JOURNAL of THE IRON AND STEEL INSTITUTE

VOL. 161 PART 4

APRIL 1949

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PUBLISHED MONTHLY

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SUBSCRIPTIONS

Members : Free
Extra Copies 7s. 6d. each

Non-Members : £5.0.0 per annum
Single Copies 10s. each

EDITORIAL AND ADVERTISEMENT OFFICES

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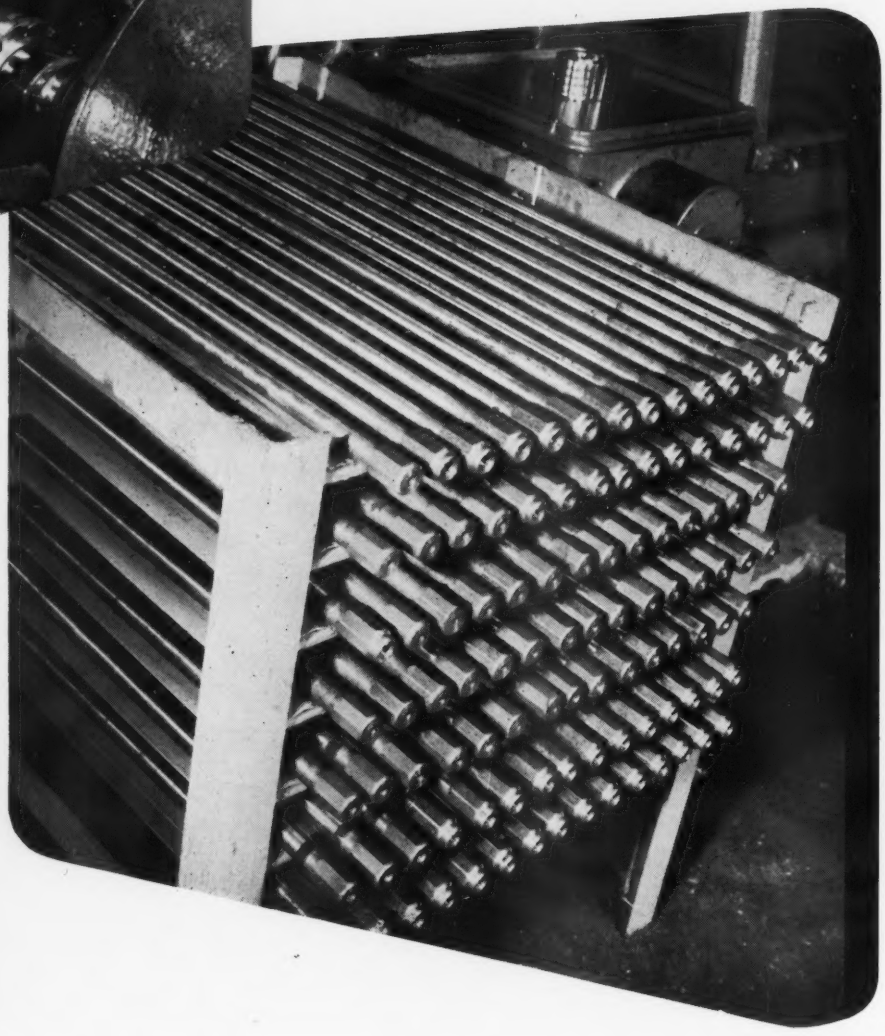

ESC

ENGLISH STEEL CORPORATION LTD

VICKERS WORKS SHEFFIELD

JAMES SPENCER HOLLINGS, C.B.E.

MR. JAMES SPENCER HOLLINGS was initially trained as a mining engineer, but entered the steel industry in 1893 under J. H. Darby of the Brymbo Steel Co., Ltd., the first man to work the basic open-hearth process in this country, starting it in 1884 Mr. Hollings was associated with this company for some thirty years and was appointed Managing Director in 1914. During this period he travelled extensively in connection with the many developments then taking place in the iron and steel industry, and thus built up a very comprehensive knowledge of the industry abroad, more particularly in Germany and the United States of America.

After the Brymbo Steel Co., Ltd. was absorbed by Baldwins, Ltd., he served under another notable pioneer, Sir John Roper Wright, who was associated with Sir William Siemens when the acid open-hearth method of steelmaking was developed. Subsequently, Mr. Hollings served under Sir John Roper Wright's successor, Sir Charles Wright, and later was appointed Managing Director and Vice-Chairman of Guest Keen Baldwins Iron and Steel Co., Ltd. He retired from these positions in 1945, in order to leave the way clear for younger men, but retained his seat on the Board. During the war his advice was sought by the Ministry of Home Security and his services were recognized by the award of the C.B.E.

Although an acknowledged expert on blast-furnace and coke-oven practice, some of his most notable contributions to the industry have been in the field of design and layout of integrated plant. In the period 1928 to 1929 he was associated with the late Mr. A. K. Reece and the International Construction Co., Ltd., in the design of the works of the South African Iron and Steel Industrial Corporation, Ltd., and some seven years later he was responsible for the planning of the East Moors Works of Guest Keen Baldwins Iron and Steel Co., Ltd.

Among other activities, Mr. Hollings is a Director of Tarmac (S. Wales) Ltd., the Briton Ferry Ironworks, Ltd., the Oxfordshire Ironstone Co., Ltd., Minera Lime Co., Ltd., and is Chairman of Sinai Mining Co., Ltd., and of Tonfanan Granite Quarries, Ltd.

He served on the executive committee of the Iron and Steel Federation for several years and on the Council of The British Iron and Steel Research Association. In addition, he was Chairman of the National Association of Hematite Pig Iron Manufacturers for over ten years, and was Chairman of the Basic Pig Iron Producers Association for approximately seven years.

He became a Member of The Iron and Steel Institute in 1903, was elected a Member of Council in February, 1930, Vice-President in June, 1938, and an Honorary Vice-President in November, 1946. He was awarded the Bessemer Gold Medal in 1946 in recognition of the services he had rendered both to the Institute and to the industry.

J. S. Hollings, C.B.E.
Honorary Vice-President

PROCEEDINGS OF THE INSTITUTE

REPORTS OF COUNCIL - OFFICIAL NOTICES

REPORT OF COUNCIL FOR 1948

THE Council submit this, their Annual Report and Statement of Accounts for the year 1948, to Members for their approval at the Eightieth Annual General Meeting of The Iron and Steel Institute.

ROLL OF THE INSTITUTE

At 31st December, 1948, the membership of the Institute was 4903, an increase of 382, or 8%, over the record figure for the previous year. Details are given in Tables I and II and in Fig. 1.

During the year 583 Members and Associates were newly elected or reinstated, and the deaths of 44 were reported; 34 were struck off the Roll of Members for non-payment of their subscriptions.

OBITUARY

The Council regret to record the deaths of the following 35 Members which occurred during 1948:

BERNARD, A. C. (Carron, Falkirk)	28th August
BRABY, C. (Uckfield, Sussex) ...	20th May
BREARLEY, H. (Torquay, Devon) ...	14th July
BROWN, Sir Peter B. (Sheffield) ...	12th October
CATHCART, W. H. (Glasgow) ...	16th September
CLAYTON, Professor C. Y. (Rolla, Mo., U.S.A.)	27th June
COLDWELL-HORSFALL, Lt.-Col. J. H. (Leamington Spa)	17th March
CORDER, J. A. (London)	23rd October
FAUCILLON, H. E. C. (Paris) ...	13th March
FEATONBY, H. (Redcar)	7th October
GORDON, F. F. (Sheffield)	22nd June
GREENWOOD, The Rt. Hon. Viscount (London)	10th September
GRENET, L. (Paris)	
HARRISON, J. H. (Middlesbrough)	16th April
HERRON, J. H. (Cleveland, Ohio, U.S.A.)	29th March
HOLDEN, J. W. (Bath)	1st October
JOHNSTON, A. (Bethlehem, Pa., U.S.A.)	2nd February
KINNEY, C. L. jun. (Denver, Col., U.S.A.)	15th May
LAQUIST, O. (Stockholm)	22nd July
LEWIS, T. O. (Llanelly)	21st August
MANNOX, F. C. (Hornchurch, Essex)	1st November
MITCHELL, Sir George A. (Glasgow)	16th February
MOYSEY, J. H. (Eastcote, Middlesex)	19th May
PATERSON, Sir Clifford C. (Wembley, Middlesex)...	26th July
RILEY, J. (Oldham)...	2nd December
ROBERTSON, Sir Henry B. (Llanderfel, Merionethshire)	20th May
ROBERTSON, T. R. (Glasgow) ...	16th August
ROUTLEDGE, Lt.-Col. W. (Alne, York)	10th November
RYLANDS, Sir W. PETER (Thelwall, Cheshire)	23rd October
SMITH, A. (West Bromwich) ...	6th November
SMITH, S. (Orpington, Kent) ...	30th May
TENNENT, R. B. (Coatbridge, Lanarkshire)	4th March
THOMPSON, G. R. (Newport, Mon.)	3rd November
THOMSON, T. J. L. (Musselburgh) ...	16th October
WEST, G. P. (Hove, Sussex) ...	18th March

Table I

MEMBERSHIP OF THE IRON AND STEEL INSTITUTE AT 31ST DECEMBER, 1948

	Ordinary Membership		Joint Membership with—								Total Membership		Grand Totals
			Institute of Metals		Institution of Metallurgists		Both Institutes and Institution		Totals				
	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	
Patron	1										1		1
Members:													
Ordinary	1863	696	401	258	320	28	325	28	1046	314	2909	1010	3919
Hon. Vice-Presidents ...	9	4	2	...	...	...	...	...	2	...	11	4	15
Honorary Members ...	2	4	1	...	...	...	...	...	1	...	3	4	7
Non-paying Members	3	1	...	...	...	...	...	...	...	...	3	1	4
Life Members	57	19	5	6	5	...	1	...	11	6	68	25	93
Totals (Members) ...	1935	724	409	264	325	28	326	28	1060	320	2995	1044	4039
Associates	278	48	348	29	55	3	100	3	503	35	781	83	864
Totals (both classes)	2213	772	757	293	380	31	426	31	1563	355	3776	1127	4903

Table II

HOME AND OVERSEAS MEMBERSHIP, 1942 TO 1948

At 31st December:	1942		1943		1944		1945		1946		1947		1948	
	Class	Totals	Class	Totals	Class	Totals	Class	Totals	Class	Totals	Class	Totals	Class	Totals
Patron	1		1		1		1		1		1		1	
		1		1		1		1		1		1		1
Hon., etc., Members:														
Home	5		5		6		10		10		13		17	
Overseas ...	9		7		7		6		8		9		9	
		14		12		13		16		18		22		26
Life Members:														
Home	39		43		44		47		47		49		68	
Overseas ...	21		21		21		20		20		24		25	
		60		64		65		67		67		73		93
Ordinary Members:														
Home	1753		1883		2017		2180		2540		2771		2909	
Overseas ...	460		471		465		556		816		914		1010	
		2213		2354		2482		2736		3356		3685		3919
Associates:														
Home	261		332		438		494		560		680		781	
Overseas ...	34		37		35		42		42		60		83	
		295		369		473		536		602		740		864
Totals:														
Home	2059		2264		2506		2732		3158		3514		3776	
Overseas ...	524		536		528		624		886		1007		1127	
Total Membership		2583		2800		3034		3356		4044		4521		4903

The deaths of the following nine Members occurred before 1948, but were not previously reported:

CARRUTHERS, T. (Workington) ...	21st June, 1947
CLIFTON, J. C. (Crayford, Kent) ...	29th November, 1947
GOLD, J. D. (Weirton, West Va., U.S.A.)	—
HIBBERT, Lt.-Col. A. (Millom) ...	19th December, 1947
PRADOS URQUIJO, G. (Bilbao, Spain)	29th November, 1947
SMITH, J. (Liverpool)	30th October, 1947
TALBOT, Sir William J.	10th December, 1947
WATSON, R. (Glasgow)	27th November, 1947
WILLIAMS, G. (Birmingham) ...	3rd December, 1947

Sir W. Peter Rylands joined the Institute in 1901, became a Member of Council in 1913, and was President for the year 1926–27. Sir Peter Brown was elected a Member in 1899, a Member of Council in 1933, a Vice-President in 1943, and an Honorary Vice-President in 1945. Mr. Harry Brearley joined the Institute in 1905; he was awarded the Bessemer Gold Medal in 1920 and was elected an Honorary Member in 1942. The memberships of the following extended to over forty years: Sir Henry Robertson (1885), Mr. C. Braby (1889), Mr. J. H. Harrison (1894), Mr. J. H. Moysey (1903), Lt.-Col. W. Routledge (1903), Mr. O. Laquist (1904), Sir William Talbot (1905), and Mr. A. Johnston (1907). Lord Greenwood became a Member in 1939.

PROPOSED CHANGE IN THE BYE-LAWS

Membership; Subscriptions

At the Autumn General Meeting, 1948, the President (Sir Andrew McCance, LL.D., D.Sc., F.R.S.) announced that a resolution to amend Bye-Laws Nos. 3, 21, 35, and 36, concerning membership of the Institute, the age of Associate Members, and the annual subscriptions payable, would be proposed at the Annual General Meeting in 1949. Details of these changes were recorded in the Proceedings of the Autumn Meeting, on page 187 of the March, 1949, issue of the *Journal*.

CHANGES ON THE COUNCIL

President

Sir Andrew McCance, LL.D., D.Sc., F.R.S., succeeded Dr. C. H. Desch, F.R.S., as President at the Annual General Meeting, 1948.

Honorary Treasurer

At the Autumn Meeting, 1948, the President (Sir Andrew McCance, LL.D., D.Sc., F.R.S.) announced that the Hon. R. G. Lyttelton had expressed the desire to resign at the end of 1948 from the position of Honorary Treasurer, which he had held since May 1942, owing to his other commitments; his resignation had been accepted with regret, and as a mark of the Council's appreciation of his services to the Institute, they had nominated him to be a Vice-President.

Mr. James Mitchell, C.B.E. (Vice-President), agreed to serve as Honorary Treasurer as from 1st January, 1949.

Other Changes

During 1948 Mr. Gerald Steel was nominated to be a Vice-President, and Mr. T. Jolly and Mr. W. Barr were elected Members of Council. Sir John Duncanson was nominated to be an Honorary Vice-President on his resignation from the position of Commercial and Technical Director of the British Iron and Steel Federation, as a tribute to his services to the Institute and the industry ; and Mr. Edward Senior was nominated to be an Honorary Member of Council in succession to Sir John Duncanson on taking up the appointment of Commercial Director of the Federation.

The following agreed to serve as Honorary Members of Council during their presidencies of the societies named, in succession to their predecessors ; Sir Arthur Smout (Institute of Metals, following Sir Paul G. J. Gueterbock, K.C.B.), Mr. F. Shepherd (Cleveland Institution of Engineers, following Mr. Chris Moody), Mr. H. F. Padbury (Ebbw Vale Metallurgical Society, following Mr. Hemingway Jones), Mr. W. R. Berry (Leeds Metallurgical Society, following Professor A. Preece), Mr. H. M. Henderson (Lincolnshire Iron and Steel Institute, following Wing Commander J. B. R. Brooke), Mr. A. H. Goodger (Manchester Metallurgical Society, newly affiliated), Mr. G. H. Latham (Newport and District Metallurgical Society, continued presidency), Mr. Basil Doncaster (Sheffield Society of Engineers and Metallurgists, following Mr. A. Firth), Mr. W. M. Larke Staffordshire Iron and Steel Institute, continued presidency), Mr. T. J. Canning (Swansea Metallurgical Society, following Mr. E. A. Davies), and Dr. C. Sykes, F.R.S. (Sheffield Metallurgical Society, following Mr. T. F. Russell).

In accordance with Bye-Law No. 10, the following

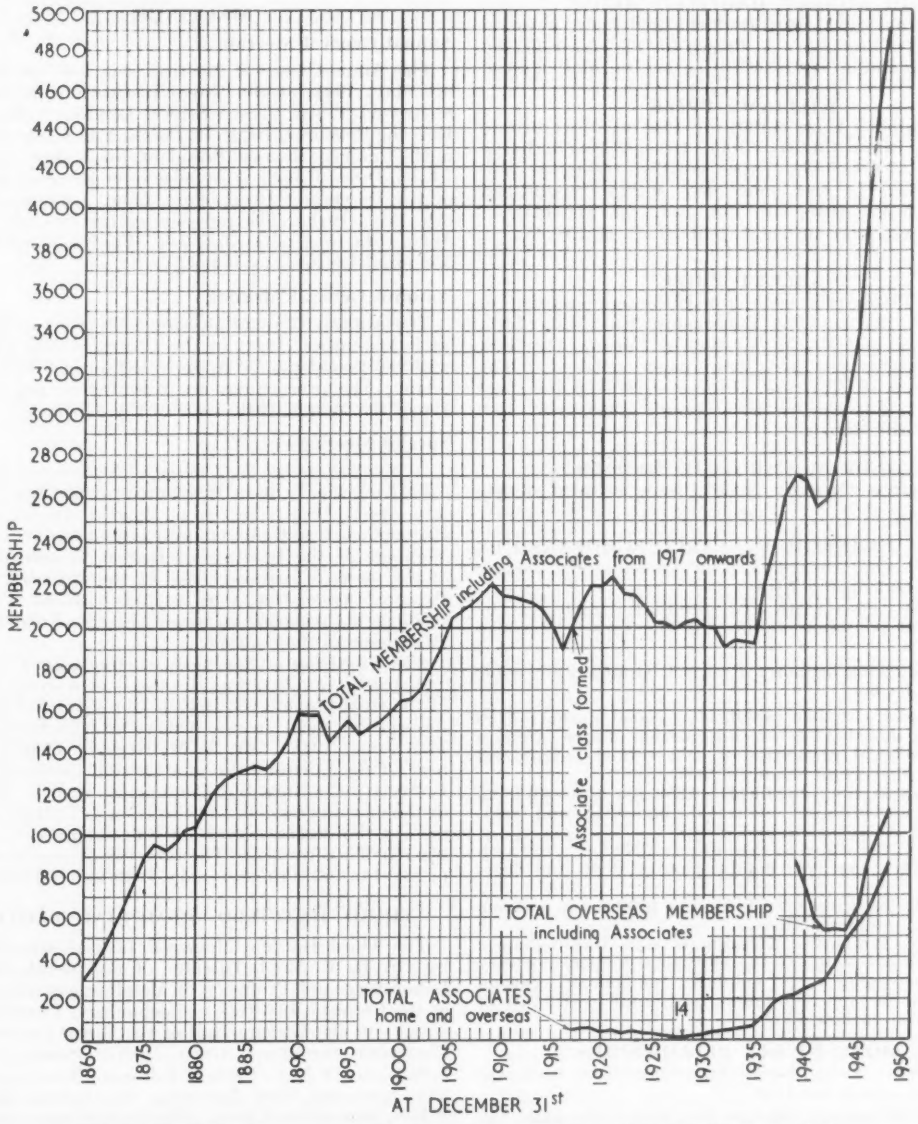

Fig. 1—Variation in membership since the foundation of the Institute in 1869

names of Vice-Presidents and Members of Council due to retire at the Annual General Meeting, 1949, were announced, at the Autumn Meeting, 1948:

Vice-Presidents—Captain H. Leighton Davies, Mr. G. H. Latham, and Mr. J. Sinclair Kerr.

Members of Council—Mr. T. Jolly, Mr. F. Saniter, Mr. W. F. Cartwright, Dr. J. W. Jenkin, and Sir Arthur Matthews.

No other Members having been nominated up to one month before the Annual Meeting, the retiring members are presented for re-election.

BESSEMER GOLD MEDAL

The Bessemer Gold Medal for 1948 was awarded to Mr. W. J. Dawson, C.B.E., in recognition of his contribution to the development of steel castings and to the production of alloy and heat-resisting steels.

SIR ROBERT HADFIELD MEDAL

The second Sir Robert Hadfield Medal was awarded to Mr. (now Professor) A. Preece for his researches on the scaling and on the overheating and burning of steel.

WILLIAMS PRIZE

The Williams Prize (£100) for 1948 was awarded to Mr. J. S. Bryan (Messrs. John Lysaght's Scunthorpe Works, Ltd.) for the paper entitled "*Gaseous and Liquid Fuels in Iron and Steel Works*" (published in the *Journal*, 1948, vol. 158, Jan., pp. 111–124), of which he was joint author with Mr. J. B. R. Brooke.

ABLETT PRIZE

Ablett Prizes (£50 each) for 1948 were awarded to Mr. G. S. Martin (The Lanarkshire Steel Co., Ltd., Flemington) and Mr. M. Y. Harvey (Messrs. Colvilles, Ltd., Glengarnock) for their paper entitled "*The Maintenance of Electrical Machinery in Iron and Steel Works*" (published in the *Journal*, 1948, vol. 158, Apr., pp. 510–520).

ANDREW CARNEGIE MEDALS

No Andrew Carnegie Medals were awarded during 1948.

ANDREW CARNEGIE RESEARCH SCHOLARSHIPS

The following Andrew Carnegie Travelling Scholarship was awarded during 1948:

A. W. Postlethwaite (Stafford): £400 for the study of powder metallurgy in the United States of America.

The following ordinary Research Grants were made during the year:

Robert Guenot (Sheffield) (second grant): £100 (for six months) for the continuation of a research on the electrical properties of cold-worked metals and alloys (first grant made in 1947).

Lichang Hsu (Sheffield): £250 for a research on the constitution of quenched, annealed, and cold-worked steel (carbon and alloy).

N. H. Polakowski (Swansea): £270 for a research on the hot and cold deformation of steels and other metals.

E. T. Turkdogan (Sheffield): £250 for a research on slag–metal reactions.

W. J. Williams (Alvechurch, near Birmingham): £250 for a research on the individual influence of very low percentages of sulphur, manganese, silicon, phosphorus, and aluminium, on the microstructure of pure iron–carbon alloys.

MOND NICKEL FELLOWSHIPS

The Mond Nickel Fellowships Committee made the following awards for 1948:

G. S. Campbell (Plessey Co., Ltd.): To study the organization from research to large-scale production of specialized metallurgical industries in the United States of America and in Canada (up to a maximum of £950).

S. J. Garvin (Murex, Ltd.): To study the application of sponsored research and administrative methods employed in the powder metallurgical industries of the United States of America (up to a maximum of £850).

A. I. Nussbaum (Thos. Firth and John Brown, Ltd.): To study the application of rolling-mill research, mill-plant development, and theory of rolling, to the manufacture of rolled steel products in the United States of America (up to a maximum of £950).

The awards made in 1947 to Mr. D. R. G. Davies and Mr. L. H. Walker were increased to £950 each.

The conditions governing the awards of Mond Nickel Fellowships are printed on page 123 of the May, 1947, issue of the *Journal*.

The Institute continued to provide secretarial services for the Committee.

MEETINGS

Annual General Meeting

The Annual General Meeting was held on 5th and 6th May, 1948, at the Royal Institution of Chartered Surveyors, Great George Street, London, S.W.1. The Retiring President, Dr. C. H. Desch, F.R.S., was followed in the Chair by the new President, Sir Andrew McCance, LL.D., D.Sc., F.R.S. A Luncheon for Members was held at the Dorchester Hotel, Park Lane, London, W.1, on 6th May, 1948. The proceedings are recorded in the June, 1948, issue of the *Journal*. (For the Third Hatfield Memorial Lecture, *see* below.)

Autumn General Meeting

The Autumn General Meeting took place on 10th and 11th November, 1948, in the Offices of the Institute, with the President, Sir Andrew McCance, F.R.S., in the Chair. The proceedings are recorded on pages 187 to 190 of the March, 1949, issue of the *Journal*.

Special Meetings

A Symposium on the Peeling of Whiteheart Malleable Cast Iron was held in the Offices of the Institute, on 8th April, 1948; Mr. J. G. Pearce, Director of the British Cast Iron Research Association, was in the Chair. Members of the Institute of British Foundrymen and of the staffs of member-firms of the British Cast Iron Research Association, were invited to attend. The proceedings are recorded on pages 17 to 34 of the January, 1949, issue of the *Journal*.

The Protection of Steel against Atmospheric Corrosion and Marine Fouling was discussed at a Joint Meeting of the Institute and the British Iron and Steel Research Association, held in the Offices of the Institute, on 17th June, 1948. Mr. T. M. Herbert, Deputy Chairman of the Corrosion Committee and Chairman of the Protective Coatings Sub-Committee, was in the Chair at the morning session, and Professor J. E. Harris, Chairman of the Marine Corrosion Sub-Committee, took his place in the afternoon. The proceedings are recorded on pages 91 to 102 of the February, 1949, issue of the *Journal*.

THIRD HATFIELD MEMORIAL LECTURE

The Third Hatfield Memorial Lecture was delivered by Dr. R. F. Mehl, Director of the Metals Research Laboratory and Professor of Metallurgical Engineering at the Carnegie Institute of Technology, Pittsburg, Pa., U.S.A., in the Lecture Hall of the Royal Institution of Chartered Surveyors, Great George Street, London, S.W.1, on 5th May, 1948, at 8.30 p.m. The President of The Iron and Steel Institute, Sir Andrew McCance, F.R.S., was in the Chair. The lecture was printed on pages 113 to 129 of the June, 1948, issue of the *Journal*.

IRON AND STEEL ENGINEERS GROUP

The Engineering Committee, which organizes the activities of the Iron and Steel Engineers Group, was composed of the following (from May, 1948):

Chairman

Mr. W. F. CARTWRIGHT

Members

Major W. R. BROWN, D.SO. .	Mr. J. F. R. JONES
Mr. J. BUCHANAN	Mr. H. MARDON
Mr. H. S. CARNEGIE	Mr. G. A. PHIPPS
Mr. M. FLENNES	Mr. L. ROTHERA
Mr. F. B. GEORGE	Mr. F. SANITER
Mr. D. C. HENDRY	Mr. BEN THORNTON

Ex-Officio

Sir ANDREW MCCANCE, F.R.S. (President)
The Hon. R. G. LYTTELTON (Honorary Treasurer) (till 31st December, 1948)
Mr. JAMES MITCHELL, C.B.E. (Honorary Treasurer) (from 1st January, 1949)

Three full-day meetings were held at the offices of the Institute on the undermentioned dates for the discussion of the papers listed; accounts of the meetings will be found in the issues of the *Journal* mentioned.

Wednesday, 18th February (1948, vol. 159, Aug., pp. 415–424; vol. 160, Sept., pp. 85–94)

- "Gaseous and Liquid Fuels in Iron and Steel Works," by J. B. R. Brooke and J. S. Bryan.
- "Soaking Pits," a group of papers collected by the Society of Furnace Builders and presented by its Chairman, Mr. H. Southern.

Tuesday, 22nd June (1948, vol. 160, Nov., pp. 303–310; Dec., pp. 417–428)

- "Electric Control Gear for Steel-Mill Auxiliaries," by R. A. West.
- "Electronic and Servo Electronic Controls and their Application to the Iron and Steel Industry," by W. G. Thompson.
- "The Maintenance of Electrical Machinery in Iron and Steel Works," by G. S. Martin and M. Y. Harvey.

Wednesday, 24th November (1949, vol. 161, Apr., pp. 361–364; vol. 162, July)

- "Belt Conveyors, Bunkers, and Chutes for Iron and Steel Works," by J. Brimelow.
- "Ore Discharging," by G. T. Shoosmith.
- "Specialized Rolling Stock for Iron and Steel Works," by T. H. Stayman and D. R. Brown.

Joint Meetings which were held with Affiliated Local Societies are referred to below. In addition, a Joint Meeting was held in Glasgow with the West of Scotland Iron and Steel Institute, on 30th January, 1948.

PUBLICATIONS

The *Journal* was published in twelve monthly parts, divided into volumes 158 to 160; indexes and binding cases are being prepared.

Special Reports—"Reports of the Affiliated Local Societies": *Special Report No.* 39, issued in respect of 1947, was published early in 1948.

Translation Service—Translations of thirty-eight foreign technical papers (Nos. 329 to 366) were issued. The charge for all translations in the Series was increased to £1 each (10*s.* for each additional copy of the same translation). The Council tender their thanks to those organizations and individuals by whom translations were made available. A number of translations, which were not suitable for inclusion in the Series, were also made for Members at their own expense.

LIBRARY AND INFORMATION SERVICE

Joint Library

The increase in the use of the Library which has been noted in past years continued. The number of publications loaned in 1948 was 10,041, compared with 8675 in 1947 and 7514 in 1946. Members who cannot call personally are reminded that publications can be borrowed by post.

About 700 scientific proceedings and technical journals are received in the Library, the majority of which are bound and filed for permanent reference. During 1948 over 200 textbooks were added. The Council wish to thank those authors and publishers who presented copies of books and papers.

Co-operation was maintained with other organizations, and good use made of the reciprocal arrangement for the loan of books from the Science Library, the National Central Library, and The Institution of Civil Engineers.

Photostat and micro-film copies of articles can be supplied to Members. (For details of services to the British Iron and Steel Research Association, *see* below.)

Information Service

The number of enquiries dealt with was greater than in the previous year. The number of abstracts prepared for publication in the *Journal* was 4248 in 1948, 3066 in 1947, and 2401 in 1946.

The Council wish to draw the attention of Members to the services offered, which include the answering of enquiries on scientific and technical literature, and the supply of bibliographies. It is not a function of the Institute to give the type of advice which is the field of the metallurgical consultant.

EDUCATION

Joint Committee on Metallurgical Education

A pamphlet giving the Committee's "*Recommendations on Qualifications for Entrance to University Schools of Metallurgy*," and a second edition of the brochure, "*Metallurgy—A Scientific Career in Industry*," were published in April and May, 1948, respectively. The Committee is giving special attention to the type of training and the range and extent of knowledge which is desirable for metallurgists entering industry from Universities and Technical Colleges. Collaboration was established with the Recruitment and Training Committee of the British Iron and Steel Federation.

The Committee is organized by The Iron and Steel Institute, the Institution of Mining and Metallurgy, the Institute of British Foundrymen, The Institute of Metals, and the Institution of Metallurgists, and the secretarial arrangements are provided by The Iron and Steel Institute.

National Certificates in Metallurgy

Good progress was made in the development of the scheme for National Certificates in Metallurgy. During the session 1947–48 senior courses leading to an Ordinary National Certificate were in operation in seventeen Technical Colleges, and advanced courses leading to a Higher National Certificate in eight Technical Colleges. Of the 123 candidates who entered, 74 qualified for the award of an Ordinary National Certificate, and of 38 candidates who entered 22 qualified for the award of a Higher National Certificate. Distinctions and prizes were awarded to a number of candidates. During the autumn of 1948 a number of additional schemes were approved and there was a considerable increase in the number of students entering courses.

The scheme is operated by The Iron and Steel Institute, the Institution of Mining and Metallurgy, The Institute of Metals, and the Institution of Metallurgists, in col-

laboration with the Ministry of Education, secretarial arrangements being provided by The Iron and Steel Institute.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Collaboration with the British Iron and Steel Research Association was continued on the lines previously arranged. The Institute provides library, information, abstracting, and translation services for the Research Association, any member-firm of which may, in its own right and without charge, borrow books from the library and avail itself of the information services ; the Institute handles for the Research Association requests for information on openly published literature and also the preparation of bibliographies. The *Journal* of the Institute is the primary medium for publishing the work of the Research Association, papers submitted by which, at the request of the Association, receive the same treatment as is accorded to other papers submitted to the Institute, both with regard to priority of publication and with regard to rigidity of application of the referee system. In addition, the Institute carries out certain general services on behalf of the Research Association, including educational activities, foreign relations, and holding of conferences.

The Council wish to record their appreciation of the close collaboration which has been established between the two organizations.

Reports on the activities of the Research Association have been published in the News Section of the *Journal*.

RELATIONS WITH OTHER SOCIETIES

The Institute's good relations with scientific societies and technical institutions at home and abroad were maintained and extended. This applied particularly to The Institute of Metals and the Institution of Metallurgists, many members of which are also Members of The Iron and Steel Institute.

By mutual agreement the arrangement by which the Secretary served also as Secretary of the Institution of Metallurgists and by which certain secretarial duties for the Institution were carried out by the staff of the Institute, was terminated on 20th April, 1948.

With the helpful collaboration of The Institute of Metals, accommodation for the Institution of Metallurgists is still provided in the Institute's building.

Collaboration with the Sheffield Metallurgical Association and with the West of Scotland Iron and Steel Institute was continued.

Affiliated Local Societies

The Manchester Metallurgical Society became affiliated to the Institute as from 1st June, 1948. There are now nine Affiliated Local Societies :

Cleveland Institution of Engineers
Ebbw Vale Metallurgical Society
Leeds Metallurgical Society
Lincolnshire Iron and Steel Institute
Manchester Metallurgical Society
Newport and District Metallurgical Society
Sheffield Society of Engineers and Metallurgists
Staffordshire Iron and Steel Institute
Swansea and District Metallurgical Society

Under the scheme of affiliation the societies retain their complete independence, but agree to admit Institute Members to their meetings, while the Institute pays a capitation grant of 5*s*. per Joint Member. Both parties endeavour to assist and collaborate with the other.

Announcements of Meetings of the Affiliated Local Societies were made in the News Section of the *Journal*, In addition, Joint Meetings of Affiliated Local Societies and the Iron and Steel Engineers Group were held as follows :

15th January, 1948 : Staffordshire Iron and Steel Institute
19th January, 1948 : Sheffield Society of Engineers and Metallurgists
21st February, 1948 : Swansea and District Metallurgical Society
4th March, 1948 : Leeds Metallurgical Society
18th October, 1948 : Cleveland Institution of Engineers and the Institution of Mechanical Engineers
23rd November, 1948 : Lincolnshire Iron and Steel Institute
14th December, 1948 : Ebbw Vale Metallurgical Society
20th December, 1948 : Sheffield Society of Engineers and Metallurgists

Joint Meeting

The Midland Metallurgical Societies held a Joint Meeting with the Institute in the James Watt Institute, Great Charles Street, Birmingham, on 5th February, 1948, at 6.30 P.M. Dr. W. Steven presented a paper on "*Modern Developments in Hardenability Testing.*"

Metallurgical Societies Overseas

Members or the staffs of companies which are members of the undermentioned overseas societies may pay an annual subscription to the Institute of £3 13*s*. 6*d*. instead of £4 4*s*. 0*d*., and Associates up to the age of 25, £1 11*s*. 0*d*. instead of £1 15*s*. 0*d*. ; in neither case is an entrance fee required :

American Institute of Mining and Metallurgical Engineers. (*The Associate age limit is* 33)
American Iron and Steel Institute
American Society for Metals
Association of Czechoslovak Mining and Metallurgical Engineers (Czechoslovakia)
Association des Ingénieurs sortis de l'Ecole de Liège (Belgium)
Association Luxembourgeoise des Ingénieurs et Industriels (Luxemburg)
Associazione Italiana di Metallurgia (Italy)
Australian Institute of Metals
Canadian Institute of Mining and Metallurgy
Indian Institute of Metals
Instituto del Hierro y del Acero (Spain)
Jernkontoret (Sweden)
Koninklyk Instituut van Ingenieurs (Holland)
Norsk Metallurgisk Selskap (Norway)
Société Française de Métallurgie (France)
Société Royale Belge des Ingénieurs et des Industriels (Belgium)
Verein Schweizerischer Maschinen-Industrieller (Switzerland)

At the first General Meeting of the Instituto del Hierro y del Acero, held in Madrid from 23rd to 26th November, 1948, the Institute was represented by Dr. C. Sykes, F.R.S.

Col. N. Watson, O.B.E., formerly of the British Control Commission in Austria and now connected with the Oesterreichische Alpine Montan Gesellschaft, was appointed the Institute's Honorary Representative in Austria.

Representation at Meetings

The Institute was represented at the following meetings by the persons named :

First International Powder Metallurgy Conference, Graz, Austria, 12th to 16th July, 1948 : Dr. C. Sykes, F.R.S.
International Geological Congress, London, 25th August to 1st September, 1948 : Dr. C. H. Desch, F.R.S.
Royal Society Conference on Scientific Information, London, 21st June to 2nd July, 1948 : The Secretary, Assistant Secretary, and Information Officer.

Association Technique de Fonderie, XXIIeme Congrès de Fonderie, Paris, 8th and 9th October, 1948 : Dr. W. C. Newell.
Société Française de Métallurgie, Paris, 18th to 23 d October, 1948 : Dr. C. H. Desch, F.R.S.

The Institute was also invited to be represented at the Fiftieth Anniversary Meeting of the Canadian Institute of Mining and Metallurgy, held in Vancouver, British Columbia, from 5th to 8th April, 1948.

Invitations to attend a Joint Meeting of the British Glaciological Society, the British Rheologists Club, and The Institute of Metals, held in London on 29th April, 1948, and a Conference on Light Metals, in Leoben, Austria, from 23rd to 25th June, 1948, were received.

PRESENTATIONS

The Council extend their thanks to the British Aluminium Co., Ltd., for the presentation of a new pair of lift gates for the ground floor of the Institute's building ; and to Mr. R. Mather for the presentation of a photograph of the Iron Pillar at Delhi.

HONOURS CONFERRED ON MEMBERS

The Council congratulate the many Members on whom honours have been bestowed or who have received appointments during the year ; their names have been recorded in the " News of Members " columns of the *Journal*.

STAFF

Dr. M. A. Vernon, Information Officer, and Dr. N. Stuart, Education Officer, resigned their appointments during the year.

The Council wish to record their appreciation of the services rendered by all members of the Staff.

REPRESENTATIVES

The following is a list of the Institute's representatives at 1st January, 1949 :

British Cast Iron Research Association : Professor T. Turner.

British Corporation Register of Shipping and Aircraft, Technical Committee : Sir Andrew McCance, F.R.S.

British Electrical and Allied Industries Research Association,
Sub-Committee J/E, Joint Committee, Steels for High Temperatures : Dr. J. W. Jenkin ; *one appointment open*.
Sub-Committee F/J, Earthing to Water Mains : Dr. J. C. Hudson.

British Iron and Steel Federation,
Statistical Committee : Mr. K. Headlam-Morley.
Films Panel : Mr. K. Headlam-Morley.

British Iron and Steel Research Association, Council : Professor J. H. Andrew, Mr. N. F. Astbury, Mr. Arthur Dorman, Dr. E. Gregory, Sir William Griffiths, D.Sc., Professor R. Hay, Mr. T. M. Herbert, The Hon. R. G. Lyttelton, Dr. W. J. Rees.

British Refractories Research Association, Council : Mr. J. Sinclair Kerr.

British Standards Institution,
General Council and Executive Committee : Mr. W. Gregson (representing the Founder Institutions).
Engineering Divisional Council E/- : Mr. J. Sinclair Kerr, Mr. Vernon Harbord, Mr. K. Headlam-Morley.
Chemical Engineering Industrial Standards Committee CHE/- : Mr. E. F. Law.
Technical Committee CHE/17, Symbols used in Diagrams of Chemical Engineering Plant : Mr. A. E. Chattin.
Sub-Committee CHE/18/2, Quality (Metallic Finishes) : Mr. T. W. Whiting.
Sub-Committee CHE/18/4, Phosphate Coatings : Dr. J. C. Hudson.
Technical Committee ELE/28, Fans : Mr. A. F. Webber, Dr. A. M. Burdon.
Technical Committee HIB/15, Pressed Steel Galvanized Rainwater Goods : Dr. A. M. Burdon.
Iron and Steel Industry Standards Committee ISE/- : Mr. F. H. Saniter.
Technical Committee ISE/1, Co-ordination of Iron and Steel Specifications : Mr. S. Barraclough.
Technical Committee ISE/6, Steel Castings : Mr. A. B. Lloyd.
Technical Committee ISE/8, Creep Properties : Mr. L. Rotherham.
Technical Committee ISE/11, Galvanized Corrugated Steel Sheets : Dr. J. C. Hudson.
Technical Committee ISE/15, Iron and Steel for Shipbuilding : Sir Edward J. George.
Technical Committee ISE/17, Cast Iron Columns for Street Lighting : Mr. J. G. Pearce.
Technical Committee ISE/28, Protective Coatings for Iron and Steel : Dr. J. C. Hudson.
Technical Committee ISE/35, Cast Iron : Mr. J. G. Pearce.
Technical Committee ISE/32, Iron and Steel Terms and Definitions : Mr. A. E. Chattin.
Technical Committee MEE/23, Indentation Hardness Testing : Mr. J. Woolman.
Technical Committee MEE/25, Testing of Metal Sheets and Strip : Dr. A. M. Burdon.
Technical Committee MEE/32, Engineering Symbols and Abbreviations : Dr. A. M. Burdon.
Sub-Committee NFE/-/5, Terminology of Casting Defects : Mr. G. T. Harris.
Technical Committee PSM/2, Welders' Goggles : Dr. C. H. Desch, F.R.S.
Solid Fuel Industry Standards Committee SFE/- : Mr. A. F. Webber.
Technical Committee SFE/1, Nomenclature and Definitions for Solid Fuel Burning Appliances : Mr. A. F. Webber.
Technical Committee SFE/2, Underfeed Stokers : Mr. A. F. Webber.
Technical Committee SFE/9, Temperature Measurement, Gas Flow, and Pressure Measurement : Mr. Neil H. Turner.
Sub-Committee SFE/9/1, Temperature Measurement : Mr. Neil H. Turner.
Sub-Committee SFE/9/2, Fluid Meters and Flow Measurement : Mr. Neil H. Turner.
Technical Committee SFE/17, Sampling and Analysis of Flue Gases : Mr. F. A. Gray.
Units and Technical Data Co-ordinating Committee M/1 : Sir Wm. Larke.
Letter Symbols Committee M/4 : Dr. A. M. Burdon.

City and Guilds of London Institute, Advisory Committee on Metallurgy : Dr. J. W. Jenkin.

Cleveland Institution of Engineers, Council : Mr. Arthur Dorman.

Constantine College, Advisory Foundry Committee : Mr. W. W. Stevenson.

Ebbw Vale Metallurgical Society, Council : Mr. R. A. Hacking.

Empire Council of Mining and Metallurgical Institutions : Mr. K. Headlam-Morley, Mr. J. Sinclair Kerr.

HATFIELD MEMORIAL LECTURE COMMITTEE : Mr. K. Headlam-Morley, Dr. C. Sykes, F.R.S.

HONG-KONG UNIVERSITY, Home Committee : *appointment open.*

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, Board of Governors : Dr. C. H. Desch, F.R.S.

IMPERIAL INSTITUTE, Mineral Resources Department, Iron and Ferro-Alloy Metals Committee : Mr. K. Headlam-Morley.

INSTITUTE OF FUEL, Council : Professor R. J. Sarjant.

INSTITUTE OF PHYSICS, Industrial Radiology Group, Sub-Committee on Terminology relating to Casting Defects revealed by X-Rays : Dr. R. Jackson.

INSTITUTION OF CIVIL ENGINEERS, Committee on Soil Corrosion of Metals and Cement Products, Sub-Committee on Soil Corrosion of Metals : Dr. J. C. Hudson.

INSTITUTION OF MECHANICAL ENGINEERS, Research Committee on High-Duty Cast Irons for General Engineering Purposes : Dr. J. E. Hurst.

INSTITUTION OF METALLURGISTS, Council : Mr. H. H. Burton, Mr. J. Sinclair Kerr.

JOINT COMMITTEE ON MATERIALS AND THEIR TESTING : Mr. K. Headlam-Morley.

JOINT COMMITTEE ON METALLURGICAL EDUCATION : Dr. C. H. Desch, F.R.S., Mr. R. A. Hacking, Mr. J. Sinclair Kerr.

JOINT COMMITTEE ON NATIONAL CERTIFICATES IN METALLURGY : Mr. R. A. Hacking, Dr. J. W. Jenkin.

KING'S COLLEGE, NEWCASTLE-UPON-TYNE (University of Durham), Metallurgy Advisory Committee : Mr. J. H. Patchett.

LEEDS METALLURGICAL SOCIETY, Council : Professor A. Preece.

LINCOLNSHIRE IRON AND STEEL INSTITUTE, Council : Mr. W. B. Baxter.

LIVERPOOL UNIVERSITY, Court of Governors : *appointment open.*

LLOYD'S REGISTER OF SHIPPING, Technical Committee : Mr. H. H. Burton.

MANCHESTER METALLURGICAL SOCIETY, Council : Mr. J. Sinclair Kerr.

MOND NICKEL FELLOWSHIPS COMMITTEE : Dr. C. H. Desch, F.R.S.

NATIONAL COLLEGE FOR THE FOUNDRY INDUSTRY, Board of Governors : Mr. H. Cookson.

NATIONAL PHYSICAL LABORATORY, General Board : Mr. H. H. Burton, Dr. C. Sykes, F.R.S.

NEWPORT AND DISTRICT METALLURGICAL SOCIETY, Council : Mr. G. H. Latham.

PARLIAMENTARY AND SCIENTIFIC COMMITTEE : Mr. K. Headlam-Morley.

RAMSAY MEMORIAL LABORATORY, Advisory Committee : *appointment open.*

ROYAL SCHOOL OF MINES, Advisory Board : Mr. Vernon Harbord.

ROYAL SOCIETY :

General Board for Administering Government Grants for Scientific Investigations : The President.

National Committee on Crystallography : Dr. C. Sykes, F.R.S.

SCHOOL OF METALLIFEROUS MINING (CORNWALL), Board of Governors : *appointment open.*

SCIENCE MUSEUM, Advisory Council : *appointment open.*

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS, Council : Professor J. H. Andrew.

SHEFFIELD UNIVERSITY, Court of Governors : Sir Arthur B. Winder.

STAFFORDSHIRE IRON AND STEEL INSTITUTE, Council : Dr. J. E. Hurst.

SWANSEA AND DISTRICT METALLURGICAL SOCIETY, Council : Captain H. Leighton Davies.

WORSHIPFUL COMPANY OF BLACKSMITHS, Court of Assistants : Dr. C. H. Desch, F.R.S., The Hon. R. G. Lyttelton.

FINANCE

(The Accounts for 1948 are appended)

Sub-Committee on Finance and Administration

The finance and administration of the Institute have been examined by a Sub-Committee of the Finance and General Purposes Committee which was formed for that purpose in March 1948, with the President as Chairman. Recommendations, designed to ensure economy in administration, have been put into effect and steps have also been taken to increase revenue, notably by raising subscription rates and increasing sales of publications ; it is hoped in this way to ensure that the finances of the Institute are placed on a satisfactory basis.

The Sub-Committee also recommended that the method of presenting the annual accounts should be brought into line with modern practice and, accordingly, a number of changes have been made.

General Fund

The deficiency of the Income and Expenditure Account was £2,425, consisting of £1,704 on the year's operation, and £721 in respect of adjustments for 1947. This compares with a net deficiency of £6,682 in 1947.

Payments received from the British Iron and Steel Research Association totalled £9,963 compared with £16,429 in 1947 (including £2,963 in 1948, and £4,748 in 1947, in respect of publishing).

Income from Members' subscriptions increased from £10,879 in 1947 to £12,256 in 1948. Publications contributed £6,882 towards the Institute's income instead of showing a deficiency of £1,490 in 1947 ; details are given in a separate account.

Gross salaries were £887 less than in 1947 but net salaries were £548 higher, owing to a reduction in the contributions received from other sources. Most other items of expenditure were less, exceptions including National Insurance (increase of £80), and payments to the Historical Investigator (increase of £632) due to his having been employed full time instead of only part time as previously.

The Entrance Fees Reserve Account and the Life Composition Fund were increased by £693 and £305 respectively. Expenditure totalling £494 on repairs, decorations and equipment was charged to the appropriate reserve.

The net reduction in the Accumulated Fund and Reserves after charging the deficiency on the Income and Expenditure Account was £2,003.

Trust Funds

On the recommendation of the Auditors a separate account is submitted for the Bessemer Medal Fund, and the accounts of the Andrew Carnegie Research and Williams Prize Funds have been prepared in such a way as to show, more clearly than previously, the amounts accumulated in previous years which are available for awards.

Investments

The market value of investments held, in respect of the General and Trust Funds, was £83,474, and the cost value, at which they are taken into the respective Balance Sheets, was £68,760 ; the corresponding figures for 1947 were £79,329 and £67,357 respectively.

THE IRON AND STEEL INSTITUTE

BALANCE SHEET, 31ST DECEMBER, 1948

General Account

1947		LIABILITIES					
£	£				£	£	
		Accumulated Fund :					
21,123		Balance at 31st December, 1947			21,123		
		Add Transfer from Bessemer Medal Reserve			125		
					21,248		
		Less Loss on Realization of Investments			84		
		Excess of Expenditure over Income for year to 31/12/48 ...			2,425	2,509	
							18,739
		Reserves :					
		Entrance Fees Reserve :					
	4,470	Balance at 31st December, 1947			5,235		
	765	*Add* transferred during year ended 31st December, 1948 ...			693		
5,235							5,928
		Loans :					
4,769		Andrew Carnegie Research Fund					—
126		Williams Prize Fund					—
		Current Liabilities and Provisions :					
15,330		Sundry Creditors (part estimated)			11,504		
		Due to Life Compositions Fund			1,097		
		Due to the Sir Robert Hadfield Legacy Fund			37		
		Due to Bessemer Medal Fund			12		
444		Subscriptions in advance			471		
580		Payments received for Publications in Advance			237		
62		Bank Overdraft			—		
218		Joint Committee on Metallurgical Education			—		
151		Andrew Carnegie Research Fund			326		
—		Williams Prize Fund			47		
2,385		Sundry provisions as at 31st December, 1947 :					
		Reserve for Ten-year index			600		
		Bessemer Gold Medal		125			
		Less Transfer to Accumulated Fund		125	—		
		Library Account			500		
		Repairs, Decorations and Equipment		1,160			
		Less Transfer to Repairs Account ...	255				
		Less Transfer to Furniture Account ...	239	494	666	1,176	15,497
£50,423							£40,164

1947		ASSETS			
£	£			£	£
		Furniture and Fittings		Not valued	
30,605		*Investments at Cost as per Schedule :*		28,010	
		(Market value at 31st December, 1948—£32,489)			
		Sundry Debtors and Payments in Advance :			
	5,352	Sundry Debtors		6,377	
	12,148	British Iron and Steel Research Association		3,035	
	516	Current Accounts		698	
	525	Payments in advance		603	
18,541					10,713
1,277		*Cash in Hand and at Bank*			1,297
		Joint Committee on Metallurgical Education			144
£50,423					£40.164

Special Funds

1947					
£			£	£	
		Life Composition Fund :			
		Balance at 31st December, 1947	4,239		
4,239		*Add* Compounded during 1948	307	4,546	
		Legacy by Sir Robert Hadfield, Bt., F.R.S.	268		
296		Accumulated interest on investments	37	305	4,851
£4,535					£4,851

1947				
£		£	£	
	Life Composition Fund :			
	Investments at Cost as per Schedule	3,449		
	(Market value at 31st December, 1948—£4,459)			
4,239	Due from General Account	1,097	4,546	
	Legacy by Sir Robert Hadfield, Bt., F.R.S.	268		
	(Market value at 31st December, 1948—£279)			
296	Due from General Account	37	305	4,851
£4,535				£4,851

We have examined the above Balance Sheet of the Institute and certify it to be correct.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET,
LONDON, E.C.2.
February 24th, 1949.

(*Signed*) W. B. KEEN & CO.,
Chartered Accountants.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1948

1947		EXPENDITURE			
£	£		£	£	
		Staff Expenses:			
	23,183	Salaries	£22,296		
		Less Contributions from:			
	150	Andrew Carnegie Research Fund	150		
	1,000	Institution of Metallurgists	212		
	897	Institute of Metals	100		
	200	Joint Committee on Metallurgical Education ...	300		
	450	Joint Committee for National Certificates in Metallurgy	500		
	125	Mond Nickel Fellowships Committee	125		
			1,387		
20,361				20,909	
217		National Insurance		297	
2,447		Staff Superannuation Fund		2,356	
23,025		Total Staff Expenses			23,562
		Other Administrative Expenses:			
585		Historical Investigator: Honorarium and Expenses		1,217	
827		Library—Books and Binding		658	
1,734		Printing and Stationery		1,632	
869		Postage and Receipt Stamps		557	
983		Travelling and Entertainment: General		666	
265		,, ,, ,, Advertising		398	
756		Meetings		559	
412		Telephone and Telegrams		432	
88		Insurances		87	
41		Interest on Overdraft		—	
52		Audit Fee—1947		147	
262		Sundry Payments		336	
					6,689
		Establishment Expenses:			
1,200		Rent		1,200	
	727	Repairs and Decorations	334		
	490	*Less* Transfer from Reserve	255		
237				79	
1,262		Cleaning, Heating, Lighting, Water		1,409	
	692	Office Furniture and Fittings	239		
	350	*Less* Transfer from Reserve	239	—	
342					2,688
		Publications: (*see* Publications Account)			
18,974		1948 *Journal*: Printing, Paper, etc.		—	20,076
4,521		Other Publications: Printing, Paper, etc.			485
461		Translations: Preparation			789
		Miscellaneous:			
176		Contributions to Affiliated Local Societies		210	
		Education:			
	250	Joint Committee for National Certificates in Metallurgy	125		
	150	Joint Committee on Metallurgical Education	50		
	—	Mond Nickel Fellowships Committee	25		
400				200	
139		Presentations		—	
		Grants:			
		Joint Committee for Materials and their Testing ...	1		
		British Refractories Research Association	25		
		Sir Robert Hadfield Plaque	5		
		British Standards Institution	25		
		Mellor Memorial Fund	10		
		Parliamentary and Scientific Committee	16		
				82	
152					492
5		Bessemer Medal			—
57,768		*Carried Forward*			54,781

1947		INCOME			
£				£	£
765		*Entrance Fees*		693	
765		*Less* Transfer to Reserve		693	
—					—
		Subscriptions:			
		Members—Home: Current	7,660		
		,, Companies' Nominations	691		
		,, Arrears	265		
				8,616	
		Members—Overseas: Current	2,415		
		,, Companies' Nominations	8		
		,, Arrears	296		
				2,719	
		Associates—Current	792		
		,, Companies' Nominations	92		
		,, Arrears	37		
				921	
10,879					12,256
	3,884	*Companies' Special Subscriptions*		3,814	
	311	*Less* Transfer to Entrance Fees Account	337		
	510	,, ,, ,, Subscription Account	791		
				1,128	
3,063					2,686
		British Iron and Steel Research Association:			
		Block Grant for Services other than Publications		6,500	
		Add Proportion of Deficit for 1948		500	
11,681					7,000
		Interest on Investments (Gross):			
		General Fund		1,128	
		Life Composition Fund		136	
		Deposit Account Interest		—	
1,425					1,264
		Publications (*See* Publications Account):			
		1948 *Journal*—			
		Revenue from Advertisements and Sales and Contribution from British Iron and Steel Research Association ...			26,166
17,367					
4,638		Other Publications—Sales			1,277
637		Translations—Sales			775
		Institute of Metals:			
	800	Rent and Services		850	
	500	Library		500	
1,300					1,350
		Other Receipts:			
96		Sundries		186	
		Sale of Furniture		117	
					303
51,086		*Carried Forward*			53,077

£		£	£		£
57,768	*Brought Forward*	54,781	51,086	*Brought Forward*	53,077
	Adjustments for 1947 :			*Deficiency :*	
	British Iron and Steel Research Association Grant—Amount not receivable	410	13,363	Excess of Expenditure over Income for Year	2,204
	Printing Costs not Fully Provided :		6,681	*Less* Payable by British Iron and Steel Research Association ...	500
	Journal, 1946, No. II	146	6,682	Deficiency for 1948	1,704
	Journal Postage—1946	119		Adjustments for 1947 *per contra*	721
	Binding Cases and Index	142			2,425
		407			
—	*Less* Over-provision for Special Report No. 39	96			
		311			
		721			
£57,768		£55,502	£57,768		£55,502

PUBLICATIONS ACCOUNT

1948 Journal

EXPENDITURE	£	£	INCOME	£	£
Printing, Paper and Blocks: Text and Advertisements		15,508	Advertising Revenue (*Less* Reserve for Bad Debts)...		17,916
Bound Volumes (estimated)		220	Sales :		
Index and Binding Cases (estimated)		1,241	*Journal*—1948 Monthly *Journals* and Bound Volumes	2,074	
Packing and Postage		2,055	Back Numbers	888	
Reprints		1,052	Reprints	1,425	
Balance transferred to Income and Expenditure Account		6,090			5,287
			Contribution from British Iron and Steel Research Association ...		2,963
		£26,166			£26,166

Other Publications

EXPENDITURE	£	INCOME	
Bibliographies	19	Sales	1,277
Special Report No. 38 (Reprint)	345		
Miscellaneous	121		
Balance transferred to Income and Expenditure Account	792		
	£1,277		£1,277

ANDREW CARNEGIE RESEARCH FUND

BALANCE SHEET, 31ST DECEMBER, 1948

1947		LIABILITIES	£	£
		Amount of Original Fund $100,000 ...	21,241	
		Add amount capitalized per last Balance Sheet	4,596	
25,837				25,837
		Sundry Creditors:		
	190	Grants	850	
		Travelling Scholarships	179	
	10	Auditors' Fee	10	
200				1,039
2,500		Reserve for Travelling Scholarship:		
		Balance at 31st December, 1947 ...	2,500	
		Add Further Transfer, 1948	500	
			3,000	
		Less Grant during year	400	
				2,600
6,785		Accumulated Fund—Balance per Account annexed		6,214
£35,322				£35,690

1947		ASSETS	£	£
£	£			
29,965		Investments at cost per Schedule		33,963
		(Market value at 31st December, 1948—£42,099)		
		Cash at Bank:		
	202	On Current Account	637	
	9	On Deposit Account	9	
	23	Post Office Savings Bank Account ...	534	
234				1,180
203		Income Tax Recoverable		221
		Iron and Steel Institute:		
	151	Current Account		326
	4,769	Loan Account		—
4,920				
£35,322				£35,690

ACCUMULATED FUND, 31ST DECEMBER, 1948

£		£
300	Grants	1,142
150	Contribution to General Fund on Account of Salaries	150
10	Audit Fee	10
5	Medal	—
—	Printing and Stationery	10
—	Legal Expenses	35
—	Sundry Expenses	5
500	Reserve for Travelling Scholarships—Amount set aside	500
6,785	Balance carried forward	6,214
£7,750		£8,066

£		£	£
6,368	Balance at 1st January, 1948		6,784
	Income for Year ended 31st December, 1948:		
1,321	Interest on Investments (Gross)	1,271	
21	Interest on Deposits	11	
40	Iron and Steel Institute—Interest on Loan ...	—	
			1,282
£7,750			£8,066

WILLIAMS PRIZE FUND

BALANCE SHEET, 31ST DECEMBER, 1948

1947	LIABILITIES	£	£
£			
2,220	Capital value representing Market value of £3,000 3½% Conversion Loan at 21st September, 1926, when the Fund was inaugurated	2,220	
667	Accumulated Fund—Balance per Account annexed ...	679	
£2,887			£2,899

1947		ASSETS	£	£
£	£			
2,670		£3,452 15*s.* 7*d.* 3½% Conversion Loan (at Cost) (Market Value at 31st December, 1948—£3,673)		2,670
	59	Cash at Bank: On Current Account	150	
	5	Post Office Savings Bank Account ...	5	
64				155
27		Income Tax Recoverable		27
126		Iron and Steel Institute—Loan Account		47
£2,887				£2,899

ACCUMULATED FUND, 31ST DECEMBER, 1948

£		£	£
100	Awards	100	
—	Legal Expenses	9	
			109
667	Balance carried forward		679
£767			£788

£		£	£
643	Balance, 31st December, 1947		667
	Income for year ended 31st December, 1948:		
121	Interest on 3½% Conversion Loan	121	
2	Interest on Deposit	—	
1	Iron and Steel Institute—Loan Interest ...	—	
			121
£767			£788

BESSEMER MEDAL FUND

BALANCE SHEET, 31ST DECEMBER, 1948

LIABILITIES	£
Capital value representing Market value of £400 4% Debentures of the L.N.W. Railway	400
Income and Expenditure Account—Balance per Account annexed	12
	£412

ASSETS	£
£474 15*s.* 0*d.* British Transport 3% Guaranteed Stock ... ... (Market value at 31st December, 1948—£475)	400
Sundry Debtor—Iron and Steel Institute	12
	£412

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1948

EXPENDITURE	£
Medal	3
Balance carried forward	12
	£15

INCOME	£
Income on Investments	15
	£15

THE IRON AND STEEL INSTITUTE

SCHEDULE OF INVESTMENTS AT 31ST DECEMBER, 1948, SHOWING NOMINAL VALUES, COST AND PRESENT MARKET VALUES

Nominal Value	Nature of Security	Market Value, 31st December, 1948	Cost Value
	GENERAL FUNDS OF THE INSTITUTE		
£ s. d.		£	£
2,197 7 0	3½% War Stock	2,273	2,161
1,324 7 4	3½% Conversion Loan	1,409	1,254
2,954 1 0	4% Consolidated Stock	3,225	3,176
12,242 19 3	4% Funding Loan, 1960/90	13,974	9,512
1,000 0 0	3% Defence Bonds (P.O. Register)	1,000	1,000
2,000 0 0	3% Savings Bonds, 1955/65	2,085	2,000
2,000 0 0	Do. 1960/70	2,066	2,000
1,500 0 0	Do. 1965/75	1,541	1,500
4,854 2 0	British Transport 3% Guaranteed Stock, 1978/88	4,916	5,407
		£32,489	£28,010
	LIFE COMPOSITION FUND		
587 13 10	3½% Conversion Loan	625	513
205 15 6	3½% War Stock	213	212
681 13 0	4% Funding Loan	778	600
196 10 1	Do.	224	231
2,615 11 2	British Transport 3% Guaranteed Stock, 1978/88	2,619	1,893
		£4,459	£3,449
	ANDREW CARNEGIE RESEARCH FUND		
	(Trustees: Sir Wm. Larke, K.B.E., The Hon. R. G. Lyttelton, and N. H. Rollason)		
6,897 14 11	3½% War Stock	7,129	6,896
800 0 0	Do.	827	794
2,693 12 0	3½% Conversion Loan	2,866	2,007
3,922 14 10	2½% National War Bonds, 1951/53	4,011	3,998
1,793 15 0	British Electricity 3% Guaranteed Stock, 1968/73	1,842	1,762
2,166 18 7	4% Funding Stock, 1960/90	2,473	2,643
500 0 0	2½% Defence Bonds	500	500
1,250 0 0	3% Defence Bonds	1,250	1,250
17,812 10 3	British Transport 3% Guaranteed Stock, 1978/88	17,835	10,863
1,000 0 0	3% Savings Bonds, 1955/65	1,043	1,000
2,250 0 0	Do. 1960/70	2,323	2,250
		£42,099	£33,963
	WILLIAMS PRIZE FUND		
	(Trustees: Sir Wm. Larke, K.B.E., The Hon. R. G. Lyttelton, and N. H. Rollason)		
3,452 15 7	3½% Conversion Loan	£3,673	£2,670
	SIR ROBERT HADFIELD LEGACY		
267 11 2	3% Savings Bonds, 1955/65	£279	£268
	BESSEMER MEDAL FUND		
	(Trustees: Desmond Lysaght, The Hon. R. G. Lyttelton, and N. H. Rollason)		
474 15 0	British Transport 3% Guaranteed Stock, 1978/88	£475	—

(*Signed*) J. MITCHELL,
Hon. Treasurer

(*Signed*) K. HEADLAM-MORLEY,
Secretary

We have examined the foregoing Balance Sheets and Income and Expenditure Accounts with the Books and Vouchers of the Institute and certify them to be correct. We have also verified the balances at the Bankers and the Securities for the Investments shown above.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET, E.C.2.
February 24th, 1949

(*Signed*) W. B. KEEN & CO.,
Chartered Accountants

IRON AND STEEL
INSTITUTE PAPERS

PLANT DESIGN · MANUFACTURE · RESEARCH · DEVELOPMENT

Investigations Relating to Scaffolds in Blast-Furnaces

By G. R. Rigby, Ph.D., B.Sc., A.R.C.S.

SYNOPSIS

Investigations have been made on a number of scaffolds occurring in blast-furnaces burdened with home ores. These scaffolds presented certain similarities and as a result of laboratory examinations a general theory for the formation of scaffolds has been postulated. A scaffold found in one furnace exhibited certain marked differences, and suggestions have been made as to the variations in blast-furnace practice which may have resulted in producing these modifications.

Introduction

In this paper a scaffold is defined as an accretion deposited on the internal walls of the blast-furnace, thereby reducing the cross-sectional area of the furnace. These accretions vary with regard to their position in the furnace. Some appear to be of a soft or powdery nature and are probably of temporary duration only; others are very hard and tough, and, unless drastic steps are taken to remove them, they may persist throughout the furnace campaign. Friable accretions have been noted towards the top of the bosh region, but these are readily dislodged and do not appear to have a firm hold on the original lining. The more permanent variety of scaffold is usually found about half-way up the stack, and it is with this type that the paper is concerned.

Opinion has been expressed that any investigation into scaffold formation is an operational rather than a refractories problem, but the first stage of scaffold formation necessitates the adherence of furnace burden to the face of the brickwork, so that, initially, scaffold growth must be closely bound up with the condition of the lining surface. However, the allocation of the problem to its particular category is of small moment compared with the urgency of carrying out investigations which might lead to a reduction in the tendency for scaffold formation. Some blast-furnace managers have never been troubled with scaffolds, but those who have, and their number appears to be increasing, would agree with G. D. Elliot[1] in ranking this problem as one of the major difficulties which beset the blast-furnace operator at the present time.

SCAFFOLDS AT APPLEBY-FRODINGHAM STEEL COMPANY

The first scaffold to receive the attention of the British Refractories Research Association was that found in the No. 1 Frodingham furnace blown out in 1938 after a campaign of 12 years, during which 947,000 tons of basic iron were made. The burden consisted of a mixture of uncalcined Northants and Lincolnshire ores and Yorkshire coke. Sinter made from these ores was also included in the burden during the last two years of the campaign. The average blast temperature was 620°–760° C. and the pressure 9–11 lb.

The stack of the furnace was fitted with 10 rows of cigar coolers, and the scaffold formed between the second and sixth row of coolers from the top at distances of between 23 ft. and 32 ft. down the stack, as shown in Fig. 1.

At the centre of the scaffold the lining inside the furnace proceeding inwards from the casing consisted of the following:

(1) Two inches of yellow cork-like material which was the original slag wool packed between brickwork and casing.

(2) Nine inches of hard practically unchanged brickwork.

(3) Fifteen inches of powder where the brickwork had been completely disintegrated due to carbon monoxide disintegration. The powder consisted of broken brick and carbon, impregnated with beads of metallic lead.

(4) Thirty inches of hard scar consisting of laminated sheets of metallic iron parallel to the face of the scar which could be peeled off in layers about ⅛-in. thick. Between each layer was a thin coating of what appeared to be burden although the alkali content was high.

Manuscript received 26th October, 1948.

The work described was carried out primarily for the Blast-Furnace Refractories Joint Committee of the British Iron and Steel Research Association and the British Ceramic Research Association. The substance of this paper was presented confidentially at the Fourteenth Blast-Furnace Conference of the British Iron and Steel Research Association, on 1st October, 1947.

Dr. Rigby is Head of the Refractory Materials Section of the British Ceramic Research Association, Stoke-on-Trent.

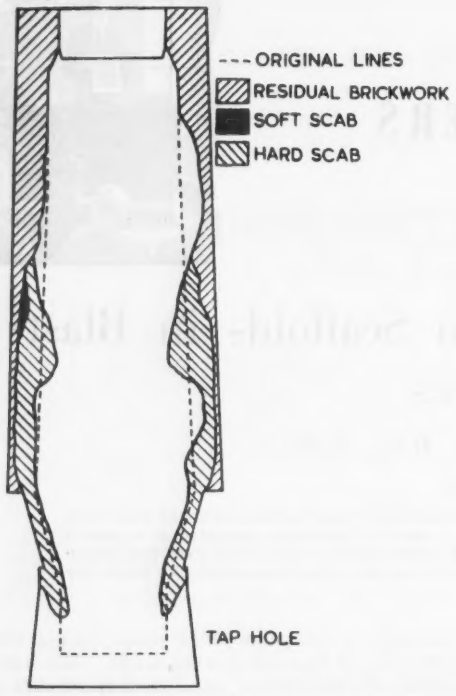

Fig. 1—The blowing-out lines of No. 1 Frodingham furnace showing the scaffold between 23 ft. and 32 ft. down the stack

The sheets of metal were exceptionally tough and pliable, the carbon content being of the order of only 0·03%. Owing to the tough nature of the scar it resisted dislodgment by pneumatic drills and consequently it was finally blasted out.

This was the second scaffold which had occurred at this works, a previous one having been found in No. 4 furnace. The No. 4 furnace scaffold started 3 to 4 ft. higher on the front side than on the back and continued 5 to 6 ft. lower at the back than the front. This difference in altitude was due to the work of the extra bosh tuyeres on the front side. The general features of this scaffold were exactly similar to those found later in the No. 1 furnace, the actual scar, which was about 2 ft. thick, being interstratified with many thin sheets of metallic iron, having a carbon content also of only 0·03%. The scaffold was removed with some difficulty, being split off layer by layer until apparently solid hard brickwork remained. However, further examination showed that there was a middle zone between the hard brickwork at the casing and the brickwork to which the scar was attached which had completely disintegrated due to carbon deposition. It is interesting to observe that this furnace was patched up and blew for another four years, until 1930, when the lining was again examined and no suggestion of a scaffold could be seen, although severe carbon disintegration had again taken place.

Another interesting point in connection with these two linings showing scaffolds was the presence of large amounts of alkali associated with the linings. One such deposit round the nose of a cooler contained on analysis 23·8% of alkali oxides, while other samples contained alkali hydroxides, carbonates, and cyanides. The management considered that the scaffold formation in No. 1 furnace coincided with the introduction of sinter into the burden which first began two years before the furnace blew out. However, it should be noticed that the burden of No. 4 furnace contained no sinter, the ores consisting of a self-fluxing mixture of Northants and Lincolnshire raw ores.

Since these observations were made on No. 4 and No. 1 furnaces, this works has experienced a tendency for scar formation to occur in many other furnaces. G. D. Elliot[1] in his report on ironmaking at the Appleby-Frodingham works has described methods of removing scaffolds at this works. In a theory of scaffold formation, emphasis was laid on the presence of potassium cyanide which was found associated with scaffolds. Elliot did not consider that alkali cyanides caused scaffolding but that they assisted in the growth of scaffolds after the first formation.

SCAFFOLDS EXAMINED AT THE WELLINGBOROUGH IRON COMPANY

This works had been free from scaffold formation until the No. 1 furnace was blown out early in 1944, after a campaign of 45 months during which 227,500 tons of basic iron were made. The burden consisted of Northants ores both raw and calcined, coke from Yorkshire and South Wales, stone and scrap. During the latter half of the campaign the ore was crushed –8 in. and a proportion of the fines was removed and not charged into the furnace.

The stack of the furnace was cooled with several rows of cigar coolers. The average blast pressure was

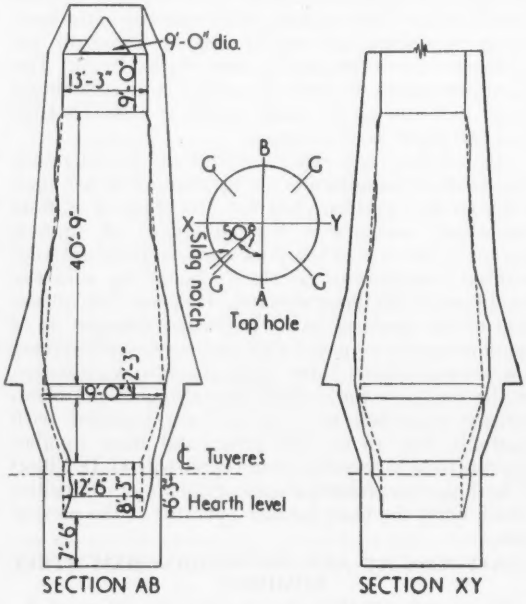

Fig. 2—The blowing-out lines of No. 1 Wellingborough furnace showing the scaffold between 22 ft. and 28 ft. below the bell

Table I

CHEMICAL ANALYSES OF THE SAMPLES

Percentage	Sample						
	1	2	3	4	5	6	7
Loss on ignition	0·48	9·00	6·65	3·99	4·24	0·12	1·29
SiO_2	55·14	49·19	48·94	47·00	35·93	31·08	17·46
TiO_2	1·38	1·23	1·38	1·24	1·05	0·80	0·65
Al_2O_3	33·13	33·45	29·58	29·15	22·30	19·13	8·44
Fe_2O_3	3·62	2·37	2·06	2·12	1·59	17·97	46·00*
CaO	0·57	0·69	0·46	0·50	0·52	10·99	13·97
MgO	0·79	0·56	0·63	0·65	0·54	3·32	3·28
K_2O	1·90	0·89	7·14	10·95	22·44	13·46	5·50
Na_2O	0·12	0·18	2·23	1·86	3·34	2·30	1·59
SO_3	0·80	0·51	0·99	0·99	0·92	1·05	1·62

* Contains metallic iron and Fe_3O_4, the total iron being reported as Fe_2O_3

9 to 9½ lb. and the blast temperature was maintained at 400° C. After blowing out, it was found that the lining in the bottom stack region had worn back fairly evenly all round the furnace but that a scaffold had formed at a position between 22 and 28 ft. below the bell (*see* Fig. 2). The scaffold had formed all round the furnace and protruded about 6 in. beyond the original lining contour. The surface of the scaffold was brown in colour and had been worn smooth by the abrasion of the burden during its descent of the furnace.

Samples were taken through the lining from the hard scar forming the face of the lining to the brickwork next to the stack plates. The first course of brickwork next to the plates was sound, but the inner courses showed disintegration by carbon deposition (samples 1 and 2). The brick just behind the scar was hard and vitrified and samples taken for analysis are reported in Table I. The scar itself was of exceptional interest in that it was composed of ore and limestone with thin lamellae of metallic iron which were parallel to the smooth face of the scar (*see* Fig. 3). The iron was practically free from carbon and it was very tough and malleable. The scar appeared hard until it was ground in a mortar when it became sticky and adhered tenaciously to the surface of the mortar. The following samples were selected for investigation :

Sample	Description
1	Portion of inner courses of brickwork showing carbon disintegration
2	Portion of inner courses of brickwork showing carbon disintegration
3	Brickwork 5 in. behind the scar
4	Brickwork 4 in. behind the scar
5	Brickwork immediately behind the scar
6	Interface between brickwork and scar
7	Sample of the scar itself.

The analyses clearly showed that the brickwork immediately behind the scar had absorbed considerable amounts of alkalis. The scar itself also contained over 6% of alkalis. In all analyses the total iron has been determined and reported as ferric oxide, but much of the iron in the scar was present as metal and lower oxides of iron than Fe_2O_3.

An X-ray investigation of the samples revealed the following information :

Sample	Description
3	Contained mullite, quartz, and cristobalite
4	Showed leucite $K_2O.Al_2O_3.4SiO_2$, and nepheline $Na_2O.Al_2O_3.2SiO_2$, the former mineral is formed when the alkali concentration is not sufficiently high to give kalsilite or kaliophilite
5	Contained kalsilite and kaliophilite, two potash alumino-silicates having the composition $K_2O.Al_2O_3.2SiO_2$
6	Consisted of kalsilite, kaliophilite, and metallic iron
7	Consisted of metallic iron, ferrous oxide, magnetite, and possibly some ferric oxide and kalsilite.

Refractoriness determinations were next carried out on the samples, since although the pure alkali alumino-silicates themselves have high melting points, comparatively viscous glasses can be formed by admixing these minerals with excess brick. Test cones were made from the above samples, and that temperature determined at which the specimens became sufficiently soft to bend under their own weights. By this means the four refractoriness values were as follows : Sample 4, 1380° C. ; sample 5, 1480° C. ; sample 6, 1200° C. ; and sample 7, 1100° C. It should be remembered that these samples would probably be sticky and soft at much lower temperatures than the above.

In April, 1946, a second furnace, which had been in

Fig. 3—The scar from the Wellingborough furnace showing the interstratified sheets of metallic iron

Fig. 4—Thin section at the brick-scaffold interface showing crystals of kaliophilite and leucite (crossed nicols) × 80

blast for 17 months, was blown out at the Wellingborough Iron Company. This furnace bore a striking resemblance to the previous one in that a scaffold had formed towards the top of the stack. The scar itself was 6 in. thick and was interstratified with thin sheets of metallic iron which were low in carbon. Between these sheets was a thin layer of burden in which calcium carbonate, iron oxides, and alkali alumino-silicates were detected by X-ray examination. At the interface between brick and scaffold there were well-developed crystals of kaliophilite and leucite (*see* Fig. 4) while the potash content was 17%. The bricks towards the middle of the lining showed some disintegration due to carbon monoxide attack but those next to the casing were unattacked. This scaffold was therefore almost identical with the one previously formed in the No. 1 furnace, and although a detailed examination was carried out no features were observed which were not present in the previous scaffold.

SUGGESTIONS FOR THE FORMATION OF SCAFFOLDS

The similarity between the structures of scaffolds at Frodingham and Wellingborough suggested that these must have had a common origin.

Any theory of scaffold formation must account for a gradual and progressive building outwards of a mass of material at a definite zone in the furnace stack. It must also account for the peculiar laminated texture of the scaffold, interstratified with thin sheets of decarburized iron and associated with alkali minerals.

The scaffold must begin by a quantity of furnace burden adhering to the surface of a zone of brickwork. Samples of the brickwork behind the scaffold at Wellingborough have shown a concentration of alkalis, not merely deposited in the pores of the brick but actually in combination with the brick as potassium alumino-silicates. Furthermore, the concentration of these potash minerals reached a maximum at the brick-scaffold interface.

At the Mellor Laboratories the action of alkali vapours on firebricks has been studied over a number of years. If a firebrick of the type used for lining blast-furnace stacks is suspended in the vapour of potassium oxide at 900–1000° C., the surface of the brick is attacked and a viscous slag begins to collect which might finally run down the sides of the specimen and drip from the bottom. As the alkali content increases, the melting point of the slag rises and it solidifies to a kind of scurf since the melting points of the pure alkali alumino-silicates are high.[2]

On the other hand, if a similar firebrick specimen is suspended in the vapour of potassium chloride, the specimen increases in weight due to absorption of potassium chloride, but no slag forms at the surface and the specimen looks unchanged.[3]

Other experiments have shown that, if silica or firebrick specimens are placed in a boat and subjected to the action of potassium chloride vapour in the absence of oxygen, there is no reaction. If, however, the experiment is repeated in the presence of oxidizing agents such as oxygen itself, or ferric oxide admixed with the specimens, the oxygen decomposes the potassium chloride vapour, forming potash (K_2O) which then reacts with the specimens to give potassium silicates and alumino-silicates, the chlorine being liberated as such or as iron chloride. Water vapour can also induce the reaction by hydrolysis of the potassium chloride with liberation of hydrochloric acid. Before potassium chloride vapour can slag firebrick materials, the presence of oxygen or water vapour is essential in order to decompose the chloride to oxide, which will then react with the firebrick forming potassium alumino-silicates.[4]

If free potash vapour were liberated in the blast-furnace we can imagine it slagging the surface of the brickwork, and the optimum slagging would take place in the hottest part of the furnace which is not the part where the scaffold forms. However, it is most likely that the alkali vapour will be present, not as oxide but as cyanide, and cyanide may be considered similar to potassium chloride in its behaviour to silicates. Arguing from the laboratory experiments above, it seems reasonable to assume that potassium cyanide vapour will not slag brickwork unless oxygen is present to allow of the formation of potash. This adequately explains why a scaffold is not formed throughout the entire stack region. In the bottom of the stack and bosh, all the burden is reduced and there are no iron oxides or water vapour to decompose the potassium cyanide which cannot therefore attack the brickwork, but is carried up the furnace. At a certain position in the stack, however, the cyanide vapour meets the iron oxide in the unreduced ore and the cyanide is then oxidized to potassium oxide which slags the brickwork, as indicated by laboratory experiments using potassium chloride. The potash continually increases in the brickwork at the position in the stack where there is free iron oxide to decompose the cyanide, and the surface of the lining gradually becomes coated with a thick viscous alkali slag to which the fine particles of burden adhere. We thus have the beginning of a scaffold, a layer of burden clinging to the brickwork, the cementing agent being viscous alkali slags. In the course of time these viscous slags absorb more

alkali oxide and crystallize as potassium alumino-silicates such as leucite or kaliophilite.

In order to explain the growth of the scaffold it is necessary to consider the action of potassium cyanide vapour on the layer of burden clinging to the walls of the furnace. F. Körber and H. H. Meyer[5] have shown that potassium cyanide and ferric oxide commence to react at 440° C., at 560° C. all the Fe_2O_3 is reduced to Fe_3O_4, and above 560° C. reduction to metallic iron takes place. Sudden heating of potassium cyanide and iron ore to 1200° C. results in violent evolution of nitrogen and carbon monoxide, pure metallic iron and potash vapour being formed. The action is influenced by the grain size of the ore, but according to Körber and Meyer grains as large as 2 to 4·5 mm. react violently with potassium cyanide, at temperatures over 800° C. The second stage in the growth of the scaffold can now be visualized. Potassium cyanide vapour reduces the surface of the ore commencing to build on the furnace sides to a thin sheet of metallic iron, which will be free from carbon since no carbon has been in contact with it or effected its reduction. This reduction is accompanied by the liberation of potassium oxide vapour which will immediately slag with the burden in the vicinity to form a viscous mass, which will then adhere in part to the thin sheet of decarburized iron and thus promote the growth of the scaffold. It is unlikely that the potash vapour will slag with the iron oxide of the burden, although potassium ferrite ($K_2O.Fe_2O_3$) is known to exist. This mineral was found in the Works III scaffold, where the potash vapour had slagged with the clay-like gangue minerals associated with the ore, forming potassium alumino-silicates. It must be considered, therefore, that the cementing agent of the scaffold is the viscous slag which is formed by the action of potash vapour on the clayey constituent of the ore. The interstratified iron sheets in the scaffold represent periods of intense reduction by cyanide vapour. These periods possibly occur when there is a sudden slip following a period of hanging which results in a violent evolution of gas, rich in cyanide vapour. Erratic working of the furnace would then be a factor in assisting the growth of the scaffolds. This process is being continually repeated in the furnace which accounts for the laminated structure of the scaffold and its gradual building outwards layer by layer.

According to this theory the tendency towards scaffold formation is influenced by the following factors :

Percentage of alkali entering the furnace in the ore, coke, and limestone
Nature of the furnace
Burdening of the furnace
Erratic working of the furnace
Leaking coolers.

Percentage of Alkali Entering the Furnace in the Ore, Coke, and Limestone—It seems probable that the alkali minerals continue to accumulate inside the furnace, as condensation of alkali vapours will take place in the cold layers of burden at the top of the stack. In other words, the alkali leaving in the blast-furnace gases is less in quantity than that entering the furnace by way of burden. The amount of alkali cyanide removed from the furnace is probably dependent on the temperature of the outgoing gases which, in turn, depends on the position of the stock line. Raising the stock-line level might lower the temperature of the outgoing gases and increase the amount of cyanide deposited in the cold layers of burden at the top of the stock column. The actual alkali content of iron ores is small, two calcined Northants ores were found to have potash 0·32 and 0·26% and soda 0·22 and 0·12%, while two raw ores had 0·48 and 0·36% potash and 0·12 and 0·16% soda, respectively. The soda percentage is usually much lower than that of the potash. Dr. Hallimond[6] gives 0·32 and 0·01 for Frodingham ore and 0·14 and 0·01 for Claxby ore. As far as can be ascertained, the potash and soda figures for coal and coke ash are of a similar order. The significant point, however, is that the alkali content in the furnace is cumulative.

Nature of the Ore—An ore which breaks down to a powder in the early stages will favour scaffold formation, since the reaction between ore and cyanide vapour is accelerated as the fineness of the ore is increased. The alkali vapours slag with the gangue minerals in the ore, so that a low-grade ore contaminated with clayey minerals is likely to promote scaffolding more readily than a high-grade lumpy ore which does not easily break down to powder. It can be appreciated that the low-grade ores of this country are likely to be associated with scaffolds more readily than the high-grade, dense foreign ores.

Burdening of the Furnace—It is generally accepted that employing a stock column more porous at the periphery than in the centre, is likely to reduce scaffolding as the walls of the furnace are being continuously swept with gas. Against this, is the fact that nearly all the potassium cyanide vapour liberated in the bosh and lower stack region will pass up the sides of the furnace and over the surface of any incipient scaffolds. In the case of Northamptonshire ores, even if the large lumps of ore are initially segregated at the walls of the furnace, they are probably readily powdered during their descent of the stack, in which case peripheral driving assists in bringing cyanide vapour in contact with the powdered ore at the furnace walls, a factor essential for the formation of scaffolds. It is probable that in every furnace there is a tendency for accretions to be deposited on the lining surface, which may, or may not, be greater than the opposing tendency for the lining surface to be worn back by the mechanical abrasion of the charge and dust-laden gases.

Erratic Working of the Furnace—It is very probable that scaffold formation is accentuated by a sudden evolution of cyanide vapour due to the furnace working erratically. Scaffold formation therefore is an accelerating process, when a small scaffold has commenced to form the free movement of the stock is interrupted, and the erratic working which results is favourable to further scaffold growth until a serious condition is present.

Leaking Coolers—Scaffold formation can probably occur owing to a cooler leaking into the furnace. The water vapour would hydrolyse the potassium cyanide to potash which would then slag the brickwork, and a scaffold could form as suggested above.

Appendix

EXAMINATION OF A SCAFFOLD AT THE SHELTON IRON AND STEEL COMPANY

By G. R. Rigby, Ph.D., B.Sc., A.R.C.S., and H. M. Richardson, B.Sc.

Recently, a most interesting scaffold has been formed in No. 6 furnace, Shelton, which is now being investigated. This firm has previously been free from scaffolds and one significant feature is that No. 6 furnace was the first furnace to be fitted with cigar coolers. The campaign lasted 7 years 1 month, during which 569,600 tons of basic iron were made, largely from Northants ore crushed below 6 in., and Shelton coke. The furnace blew on 9–10 lb. at a blast temperature of 500–550° C.

On blowing out the furnace a large scaffold was discovered all round the stack, situated from 27 ft. to 38 ft. below the bell (*see* Fig. 5). This scaffold presented different features from those described above. The inner surface of the scaffold was fairly hard and consisted of successive depositions of finely divided iron, but the decarburized sheets were completely absent. X-ray examination showed the presence of metallic iron (75%), calcium hydroxide and carbonate and iron oxides, together with a very small percentage of alkali oxides. The interior portion of the scaffold appeared very similar at all levels. It was black and consisted largely of amorphous carbon and coke with depositions of alkali chlorides, alkali carbonates, zinc oxide, metallic lead as globules, and a little iron oxide. One sample contained about 70% of carbon, 4% of zinc oxide, and 13·6% of potassium chloride. The brickwork behind the scaffold showed in places some evidence of alkali attack, but only one sample on X-ray examination revealed the presence of alkali aluminosilicates. Behind the brick-scaffold interface the brickwork was in fairly good condition and disintegration due to carbon monoxide was very small.

It is obvious that the Shelton scaffold presents several important differences from the scaffolds examined previously which may be listed as follows :

(1) The Shelton scaffold was much softer, even the hardest pieces could be disintegrated by hand
(2) It was black and not red due to the presence of coke and carbon and the comparative absence of iron ore
(3) Metal was present at the surface in a finely divided state but not as decarburized sheets of iron
(4) There was very little alkali attack as evinced by the presence of alkali alumino-silicates; on the other hand, there were large amounts of free alkali salts, mainly alkali chlorides and carbonates
(5) The scaffold contained zinc oxide and metallic lead.

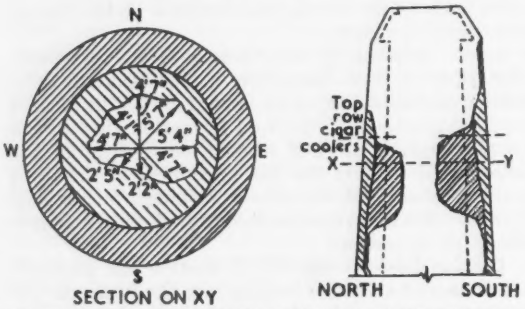

Fig. 5—The blowing-out lines of No. 6 Shelton furnace showing the scaffold between 27 ft. and 38 ft. below the bell

These differences do not necessarily mean that the scaffold at Shelton had an entirely different origin from those at Frodingham and Wellingborough; on the contrary, the differences appear to be of degree rather than of kind. In the Shelton furnace two important features appear to have modified the scaffold :

(1) The alkali vapours in the stack appeared to be chlorides rather than cyanides, and as such could not have reduced the iron to decarburized surface sheets
(2) The burden distribution in the furnace appeared to be such that the coke rather than ore was thrown to the walls of the furnace.

Thus, at the walls, relatively *little* free alkali oxides were liberated from the chlorides due to the comparative absence of oxygen owing to coke replacing ore. However, it appeared certain that small amounts of alkali oxides were liberated and these were sufficient to act as a cementing agent for the scaffold but insufficient in amount to form alkali alumino-silicates. The bulk of the alkali minerals were therefore present as chlorides and these may also have had a certain cementing action. The net result, however, is that the Shelton scaffold was a much softer and more easily disintegrated mass than the Frodingham and Wellingborough scaffolds, since coke and carbon do not supply oxygen to decompose alkali chlorides to alkali oxides, and secondly, there are no gangue minerals in the coke which would react with any alkali oxides to form highly viscous melts which would act as cementing agents. In other words, the soft nature of the Shelton scaffold was due to the iron ore at the walls being mixed with a preponderance of coke and carbon.

Acknowledgments

The author wishes to express his thanks to Mr. A. T. Green, Director of the British Ceramic Research Association for permission to publish this paper. He would also like to record his gratitude to the managements of all the works concerned in this investigation. Without their help and co-operation this paper could never have materialized. The author also gratefully acknowledges the help given to him by the following members of the British Refractories Research Association staff: Mr. W. P. Johnson for the chemical analyses, and Mr. H. M. Richardson who carried out the X-ray investigations.

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The Conversion to Oil Firing of the Open-Hearth Furnaces at Park Gate Works

By D. F. Marshall, B.Sc.(Tech.), Ph.D., and H. C. White

SYNOPSIS

The paper gives an account of the experience gained during the conversion of a complete open-hearth furnace plant to the use of fuel oil. After briefly describing the open-hearth plant the reasons for making the conversion are discussed and some consideration is given to the properties of the principal available fuels.

The details of the fuel-oil plant and the methods adopted in making the conversion are outlined.

A comprehensive system of instrumentation has been used to apply a simplified operating technique to hand-controlled furnaces. The methods of furnace control adopted and the organization required to ensure that the best use is made both of furnaces and of instruments, are given in some detail.

The operating results over a period of 57 weeks are presented and discussed under three main headings, shop layout, type of charge, and furnace performance. Under the last heading consideration has been given to the quality of the scrap and to the constitution of the charge. The flow characteristics of three types of burner and details of the influence of roof temperature on the rate of furnace working are given. The life of the refractories used is indicated ; and the essentials for fully automatic furnace control are stated

Introduction

THE object of the present paper is to give an account of the experience gained during the conversion of a complete open-hearth shop to the use of oil fuel. The subject is dealt with from a complete shop aspect as distinct from a discussion of individual units, since it became clear, at an early stage, that the results obtained on one unit were very largely affected by conditions governing the whole of the shop. It is thought that the considerable amount of literature on the subject of oil conversions already published might usefully be supplemented by dealing with the subject on this broader basis.

The large scale of the conversion has, to a certain extent, influenced the design of the plant and facilitated considerable changes in furnace-operating technique and instrumentation. It is felt, therefore, that apart from details of the actual conversion, there may be a useful purpose served in outlining how different furnace-operating technique, making full use of comprehensive instrumentation, was put into practice. In one sense, it was perhaps unfortunate that all these changes coincided with a major reconstruction of the blast-furnace plant, which meant that it was necessary to depart from the normal hot-metal practice. On the other hand, the enforced variations in practice accompanying the changing hot-metal position brought to light much about the process which might otherwise have been missed.

Description of Open-Hearth Furnace Plant

The open-hearth shop at the Park Gate Works contains nine basic furnaces, having capacities ranging from 65 to 90 tons. Hot metal, which normally forms about 40% of the charge, is stored in an active, hot-metal mixer of 400 tons' capacity. All classes of carbon steel are manufactured, ranging from dead-soft to 0·80% carbon, including high-sulphur free-cutting steels, and low-alloy steels. Semi-killed and dead-killed steels are made, so that both open-top and feeder-head moulds are in use, and about 25% of the casting is performed uphill.

Owing to reconstruction of the blast-furnace plant, the hot metal used has ranged from 35% to as low as 20% during the working period dealt with in this paper. Scrap is delivered into two scrap bays, one at each end of the shop, the pans on bogies being filled by overhead cranes fitted with magnets. Diesel locomotives place the bogies in front of the furnaces, the charging sequence being completed by high-ground-type chargers. The furnaces have been progressively increased in capacity over a number of years, although limitations of ground space have greatly influenced these changes. All the furnaces are equipped with waste-heat boilers. Gas was supplied by a battery of seven gas machines, each with a capacity of 2 tons/hr. The fuel consumption was equivalent to 6,900,000 B.Th.U. per ton of ingot, in terms of coal fed to the producers. Allowing a producer efficiency of 80%, the amount of heat in the gas at the furnace was 5,500,000 B.Th.U. per ton of ingot.

Reasons for Conversion

An alternative fuel was sought, primarily because it was necessary to increase the ingot capacity of the shop. This was not possible by extension, and to have rebuilt the plant entirely would not have given immediate results. The disadvantages of producer gas in the event of the application of the continuous working week were also considered. In addition, the coal supply position was rapidly deteriorating. The use of oil fuel appeared to offer a solution to all these problems.

The main characteristics of the most widely used industrial fuels are shown in Table I, from which it will be seen that the essential differences between oil and producer gas are :

(1) On a volume basis oil fuel is about 7000 times more concentrated in terms of heat capacity than

Manuscript received 19th October, 1948.

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Table I
PROPERTIES OF INDUSTRIAL FUELS

The weight of fuel considered is in each case 1 lb.

Fuel	Volume, cu. ft./lb.	Air Reqd. for Combn., cu. ft./lb.	Heat Generated		Vol. of Waste Gases Produced, cu. ft.	Theoretical Flame Temp., °F.	Air Reqd. per 1000 B.Th.U. Generated, cu. ft.	Volume of Waste Gas Produced per 1000 B.Th.U. Generated, cu. ft.	Luminosity Factor
			B.Th.U./lb.	B.Th.U./cu. ft.					
Blast-furnace gas	10·9	8·6	1100	107	18·4	2660	7·4	15·78	...
Producer gas	14·2	18·5	2100	150	29·9	2910	8·7	14·00	2·1
Coke-oven gas	32·6	133·7	15,400	470	153·2	3710	8·7	9·69	2·3
Pulverized coal (10% ash, 5% moisture)	0·02	130·0	13,000	650,000	137·0	3700 to 3800	10·00	10·53	4·0 to 5·0
Oil	0·018	184·0	18,700	1,041,500	194·0	3780	9·81	10·34	6·1

is producer gas. It has therefore decided advantages on questions of storage and distribution.

(2) Oil fuel, being a clean liquid, is much better suited to applications of instrumental control than is producer gas, which contains tar and soot.

(3) For equal heat release, the theoretical volume of waste gases, using producer gas, is about 35% greater than that from oil fuel. This is particularly important since it means that without any changes to checkers, flues, or exhausting systems, the potential heat release in the body of the furnace is greatly increased by converting furnaces to use oil fuel.

(4) Oil fuel develops a higher flame temperature and the flame has a higher luminosity than that of producer gas. Both these factors increase the work done by the flame in the furnace.

(5) Comparing the two fuels on an equal heat-release basis, per 1000 B.Th.U. :

6·7 cu. ft. of producer gas + 8·7 cu. ft. of air give 14 cu. ft. of waste gases,
0·001 cu. ft. of oil + 9·81 cu. ft. of air give 10·34 cu. ft. of waste gases.

Thus, using producer gas, the volume of the fuel used is large in comparison with that of the air used and of the waste gases formed.

On the other hand, with oil fuel the volume of the fuel used is almost negligible and the volume of air used is almost equal to that of the waste gases produced. These simple facts have a profound bearing on furnace design and can also influence methods of furnace operation. The latter point is discussed later in the paper.

(6) In addition to the better flame characteristics of oil, the very method of its introduction into the furnace provides better control of flame direction, the rate of combustion is far more easily controlled, and the plant required for its handling is compact, clean, and needs a smaller operating personnel. Being introduced direct into the furnace no conversion losses are involved in its application.

Initially, the possibility of an experimental plant only was considered, involving the conversion of one, or at the most two, furnaces. It was ultimately decided, however, to install the full-scale equipment and to convert all the nine furnaces. At this time there was only one blast-furnace in operation, and consequently some of the steam formerly raised by blast-furnace gas had to be obtained by burning coal under the boilers. The blast-furnace reconstruction scheme was not expected to be completed in less than

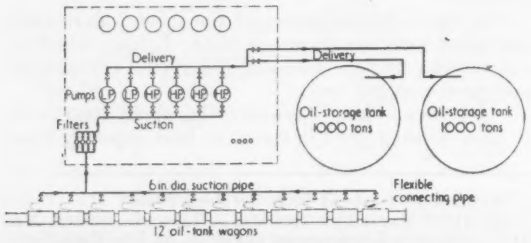


Fig. 1—Oil-transfer and storage system

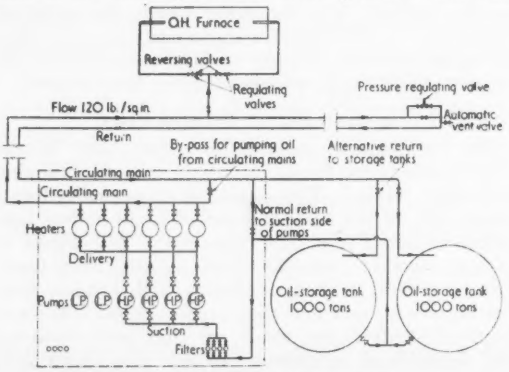


Fig. 2—Oil-circulating system

three years, and it was therefore decided to apply oil to some of these boilers. Four rolling-mill reheating furnaces were also included in the oil-firing programme. The two latter applications are mentioned because they were factors influencing the design of the oil-fuel plant.

DETAILS OF CONVERSION

Oil-Fuel Plant

A central storage and pumping station, for supplying oil to all three applications, was installed on a site 500 ft. from the nearest open-hearth furnace. Two separate oil-pumping systems were provided: (1) a low-temperature, low-pressure system for dealing with the transfer and storage of oil (*see* Fig. 1), and (2) a circulating system to supply oil at high temperature and pressure to the open-hearth furnaces (*see* Fig. 2).

The pump house (Fig. 3) accommodates all the pumps, heaters, and filters for both systems. In laying out this equipment and its connecting pipes, every endeavour was made to obtain the utmost flexibility of operation, in conjunction with adequate standby capacity, firstly, because continuity of supply to the furnaces had to be assured, and secondly, to provide the maximum possible oil-transfer rate. The high-pressure pumps are therefore each provided with double suction and delivery connections, one in each system, enabling them to perform either duty. The equipment installed in the pump house is as follows:

- Two low-pressure pumps, capacity 16 tons/hr. each at 40 lb./sq. in. pressure
- Two high-pressure pumps, capacity 15 tons/hr. each at 175 lb./sq. in. pressure
- Two high-pressure pumps, capacity 7½ tons/hr. each at 175 lb./sq. in. pressure
- Six steam-operated oil heaters giving a total oil-heating capacity of 30 tons/hr. at 95° C. oil temperature when operated on steam at 160 lb./sq. in.
- Eight oil strainers in sets of four and arranged in parallel.

All the pumps are of the steam-driven single-cylinder reciprocating type.

Oil Transfer—Alongside the 260-ft. long oil-unloading bay is a 6-in. dia. oil-suction main with 4-in. dia. branches at tank-wagon centres. Heavy fuel oil being difficult to pump when cold, a 2-in. dia. steam pipe, with ¾-in. dia. steam branches and valves for supplying the steam heating coils in the tankers, is arranged alongside the oil-suction main. It also supplies steam to a ½-in. dia. steam tracer pipe running alongside and in contact with the oil-suction main. The steam branches are in duplicate at 21-ft. centres to accommodate adjacent tankers with right-hand and left-hand steam connections. Steam and oil connections to the tankers are made by flexible metallic tubes of ¾ in. dia. and 4 in. dia. respectively. The tracer pipes and heaters are supplied at a pressure of 25 lb./sq. in. through a reducing valve from the main steam supply.

The low end of the suction main delivers into a catch pot, from which a further suction main of 6 in. dia. enters the pump house, delivering the oil by a manifold through four coarse strainers arranged in parallel. From the strainers the oil passes into a suction main, running alongside the six pumps, all of which may be used for oil-transfer duty. The pumps deliver into a main of 6 in. dia. which later divides to discharge into the top of either storage tank as required.

Oil is transferred from tankers to storage tanks at the rate of 50 tons/hr., giving an average pumping time of 7 hr. for a complete train. Adding to this the time required for shunting and connecting-up, it will be seen that a train can turn around well within 24 hr.

Oil Storage Tanks—Two storage tanks, 25 ft. in dia. and 40 ft. high, are provided, each capable of holding 1000 tons of oil. Steam heating pipes are fitted in the base of each tank to maintain stored oil at 40° C. These heaters, which are thermostatically controlled, are arranged as follows: Three heaters are provided, the middle section being placed under a shroud or inverted channel, one end being open to the contents of the tank, the other end terminating

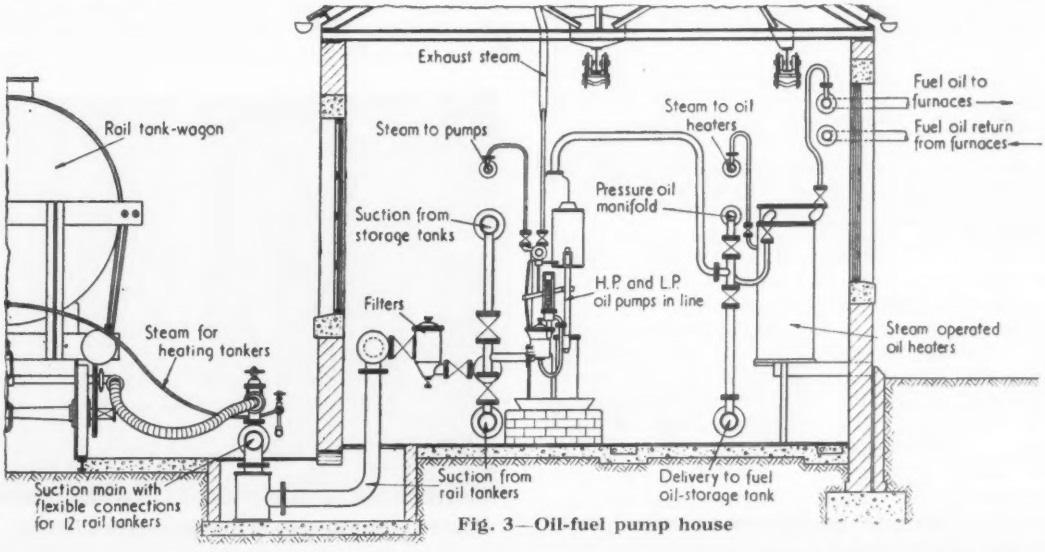

Exhaust steam
Steam to oil heaters
Fuel oil to furnaces
Fuel oil return from furnaces
Rail tank-wagon
Steam to pumps
Pressure oil manifold
Suction from storage tanks
H.P. and L.P. oil pumps in line
Filters
Steam for heating tankers
Steam operated oil heaters
Suction main with flexible connections for 12 rail tankers
Suction from rail tankers
Delivery to fuel oil-storage tank

Fig. 3—Oil-fuel pump house

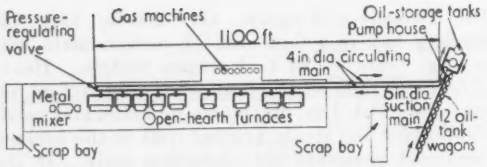


Fig. 4—Arrangement of open-hearth furnaces and oil-fuel plant

in the suction mounting. All oil drawn from the tank is thus drawn over the heater. On either side of this heater are two further heating sections for the general heating of the contents of the tanks ; these are intended to be used only during very cold weather. They can be isolated by hand-operated valves, but when in operation they are controlled by the same thermostatic valve supplying the middle section.

Although great care was taken to ensure that the foundations of the tanks were taken down to good ground, it was deemed advisable to use flexible pipes for both steam and oil connections to the storage tanks to avoid the risk of straining or breaking.

Circulating System—Four high-pressure pumps are available for the circulating system, and a pumping capacity of 22·5 tons/hr. is provided, with 100% standby capacity. Preliminary calculation showed that consumption would be an average of about 7 tons of oil per hour on the open-hearth furnace plant, with a maximum demand of 10 tons/hr. To maintain constant pressure in the circulating mains, it is essential to circulate considerably more oil than is drawn from the system. In actual practice it is found that one pump with a capacity of 16 tons of oil per hour is capable of meeting all demands.

Oil is drawn from the storage tanks *via* strainers into the pumps, which deliver it through hand-regulated steam heaters to the circulating main which extends the full length of the open-hearth shop. A 1½-in. dia. branch is provided, opposite each furnace, in the outgoing leg of the circulating main. All the unused oil is returned to the suction side of the pumps for recirculation, or alternatively to the top of the oil-storage tanks.

In order to avoid excessive pressure drop in the circulating main, which is 2200 ft. long, the oil velocity is kept below 3 ft./sec. in the 4-in. dia. main. Low circulating velocity tends to increase the temperature drop between heaters and furnaces. This is offset by thermostatically controlled, ½-in. dia., steam-tracer pipes which are arranged in contact with the oil main, both pipes being lagged together. These steam-tracer pipes are arranged in eight sections, 275 ft. long, and operate at a pressure of 25 lb./sq. in.

Pressure is maintained in the circulating main by means of a spring-loaded valve, set to give 120 lb./sq. in. This valve, which is provided with an emergency by-pass valve, is at the end of the shop remote from the pump house. The circulating main gradually rises from the pump house to permit easy drainage, and an automatic air vent is provided at the high end. The oil can be pumped from the circulating main as an insurance against heavy loss of oil in the event of rupture of the mains. Figure 4 gives the layout of the oil-fuel plant, in relation to the open-hearth furnaces and shows the two oil systems.

Furnace Structure

Since the furnaces were to be converted with as little structural alteration as possible, the alterations were confined almost entirely to the furnace ends.

Burner *A* (Fig. 5) was used throughout in the initial conversions. This burner, being water-cooled throughout its length, could have been used without the ' dog-house ' construction and would have given a larger air port with the air stream in very close proximity to the atomized oil. However, the water supply was not above suspicion, and trouble might have been experienced in exposing large areas of water-cooled surface to furnace temperatures ; the quantity of cooling water required under such conditions would have been considerable. On the other hand, the dog-house type of construction necessitates exposure to the furnace temperatures of only the tip of the burner. It was further considered futile to provide any arrangement giving control of flame direction unless the inner end of the burner could be positioned accurately. The use of a dog-house allows the flame direction to be adjusted whilst the furnace

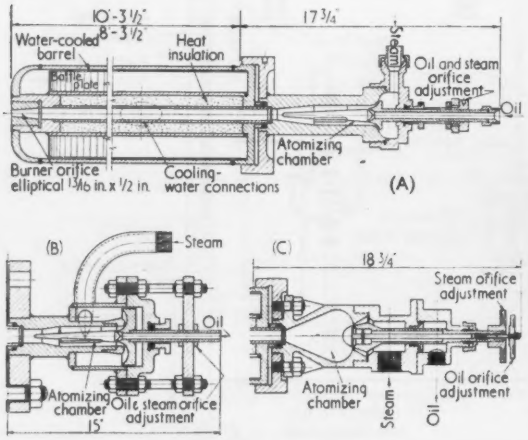


Fig. 5—Types of burner used

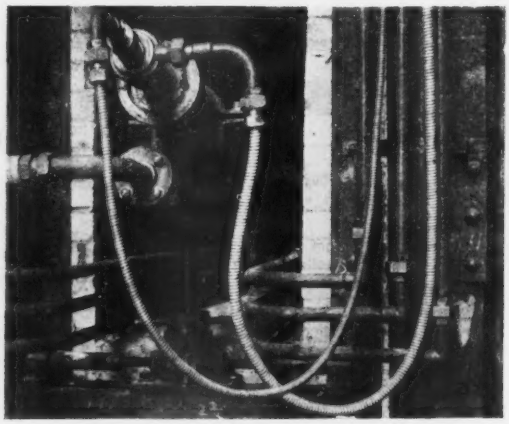


Fig. 6—Arrangement of burner supporting gear

is in operation, the air seal being maintained at the burner tip.

The burner is supported at its inner end on a water-cooled pipe-cradle, and two further pipes pass over the top of the burner and protect the face of the dog-house brickwork. The three pipes are assembled as a unit and placed inside the dog-house, on the brick floor. As they are not built into the brickwork, they are easily replaced, although very few of these pipes have been destroyed up to the present time. At the outer end the burner is carried in a cradle supported from below by a vertical screw jack giving angular adjustment to the flame. Adjustment sideways is obtained by means of two horizontal screws. The burner is held in the cradle by a clip, removal of which allows the burner to be lifted out and replaced without upsetting the flame adjustment. All this supporting gear is carried on the furnace steelwork and is provided with locking devices (*see* Fig. 6).

One large uptake is provided at each end of the furnace with the slag pocket directly underneath. Two flues from this uptake lead into the slag pockets of the larger regenerator chambers. Furnaces not having slag pockets were altered, a portion of the checker volume being allocated for that purpose. The uptake is divided, above furnace-sill level, by the dog-house brickwork which is supported on an arch built across the uptake. The actual air port extends above and on both sides of the dog-house brickwork and is shown in Fig. 7. It was realized that the oil flame, with its high velocity at the burner tip, would not fully develop for the first few feet of its length ; the port faces are therefore set back two to three feet from their original positions, which provides a larger furnace laboratory.

No attempt is made to guide the incoming air as the angular setting of the burner decides the position of the flame relative to the bath. Where possible the furnace roofs are raised, which results in most of the furnaces having horizontal arched roofs without end ramps. Roofs range in height from 5 ft. 6 in. to 7 ft. 6 in. above sill level. Part section of a typical converted furnace is shown in Fig. 8.

The checker openings are larger, being increased from $6\times4\frac{1}{2}$-in. to 6×6-in. straight-through openings.

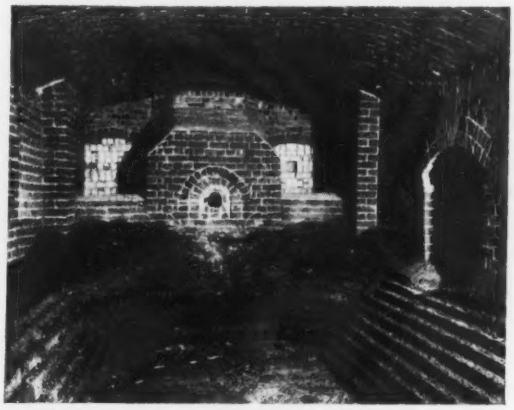


Fig. 7—Arrangement of burner and air port

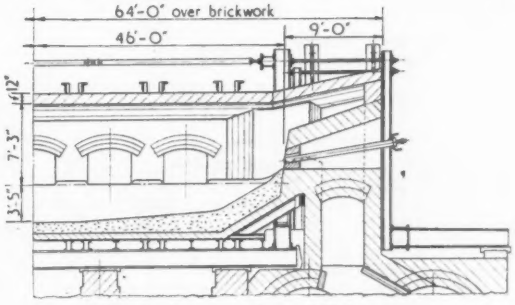


Fig. 8—Part section of T furnace

The furnace-flue system and the valves, which are of the mushroom type, are unaltered. The gas supply is sealed off and a fan is arranged to deliver air into the gas-regulating valve box, with a second fan placed on the air box. These fans have capacities of 6000 and 12,000 cu. ft./min. respectively at 2 in. W.G. The fan motors are generously rated, as atmospheric conditions in the valve cellar are not good. A control damper is placed in the outlet of the smaller fan. Control of volume from the larger fan is obtained by means of the usual valve having an air screw at charging-platform level. The damper on the smaller fan can be operated only in the cellar and is provided with a locking screw. During the first few days of furnace operation this valve is adjusted to give a balanced preheat from both checker chambers ; thereafter it remains set, giving a constant air flow through the smaller chamber. Adjustment of flow through the larger chamber, if required, is made by the use of the air-screw control. This system works well in practice, the furnace balance being very little affected by the relatively small change in air volume. No attempt is made to regulate the flow of waste gases through the chambers. The reversing gear remains unaltered and operates in the normal way.

Furnace Controls

Steam at 160 lb./sq. in. maximum, supplied from the main steam pipe running overhead, is used as the atomizing agent. The oil supply comes from the branch on the circulating main. These supplies are led into a control desk, where the flow of steam and oil to the burner is regulated and reversed. Reversing valves of the screw-down, globe type are fitted, and for fine regulation of steam and oil flow, needle-type valves are used. A small quantity of steam is allowed to flow continuously through the dead-end burner in order to keep it free from carbon deposit. This steam flows through an orifice of $\frac{1}{8}$ in. dia., placed in a pipe which by-passes both the reversing and the regulating valves. Pressure gauges on the control desk show steam and oil pressures, after the regulating valves, on both ends of the furnace. All steam and oil pipes are taken under the platform to reappear at the ends of the furnace where they are coupled to the burner by flexible pipes to allow for burner adjustment. Figure 9 gives a cross-section of the furnace shop and shows the oil system and its controls.

Conversion Programme

It was considered initially that each furnace conversion would take approximately three weeks to

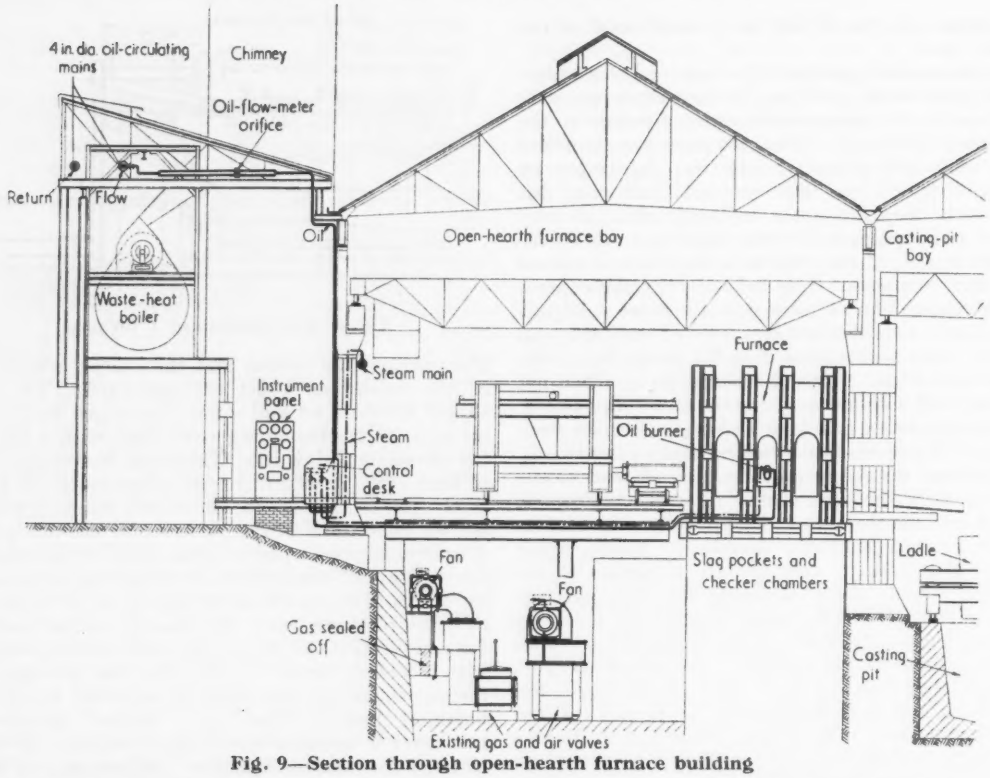


Fig. 9—Section through open-hearth furnace building

complete, as a new bottom would be required in most cases. A programme was drawn up on this assumption, taking into consideration also the general condition and expectation of life of the furnaces at that time. The first furnace was converted in three weeks; thirty-nine weeks later no producer-gas-fired furnaces were in operation. This was considered satisfactory as several gas-fired furnaces had to be taken off for normal repairs during the same period. Difficulties were experienced in obtaining all types of material and equipment, but in no case was the programme held up on that account.

It was important that output should be maintained at a high level, and consequently individual conversions were made only when the time seemed opportune. Figure 10 shows that apart from the first five weeks, when three furnaces were being converted, the average number of producing furnaces maintained was greater than seven.

INSTRUMENTATION

Description of Instruments

With producer-gas operation the chief instruments or controls were roof-pressure recorders, gas and air screw gauges for approximate flow guides, and 4-point draught indicators, supplemented by frequent draught surveys of the entire system to detect operating faults. Over a period of years, efforts had been made to use this limited equipment to obtain some uniformity of operation, and the results obtained were much better than might have been expected. For example, on the 24-hr. chart of each roof-pressure recorder, a thin band with a range of only 0·01 in. W.G. was printed, and with hand control only of gas screws, air screws, and dampers, some remarkably uniform charts were obtained, almost every furnace keeping within the limits given throughout the charge. These simple controls were supplemented by checker- and flue-temperature recorders, in addition to various types of reversing indicators.

The experience gained during this period served to indicate what instruments would be necessary on an oil-fired furnace, and what degree of furnace control could be applied to hand-controlled furnaces. The relatively high cost of oil fuel, coupled with the higher flame temperatures obtainable, made it imperative that these controls should be considerably augmented, and further, it appeared advisable that some concise instruction should be given to the furnace operators in order to obtain uniformity and economy in furnace practice.

During the period of conversion the opportunity was taken to introduce a fairly comprehensive and uniform instrumentation based on the following broad principles :

(1) Each furnace was to have similar equipment mounted on one central panel

(2) This panel was to be as near to the operating controls as possible

(3) Particular attention was to be paid to incorporating easily read indicating instruments. Recorders were to be used in every practicable case

(4) In the event of failure of any one instrument, there should be enough information remaining on the panel to enable the furnaceman to carry on without undue difficulty.

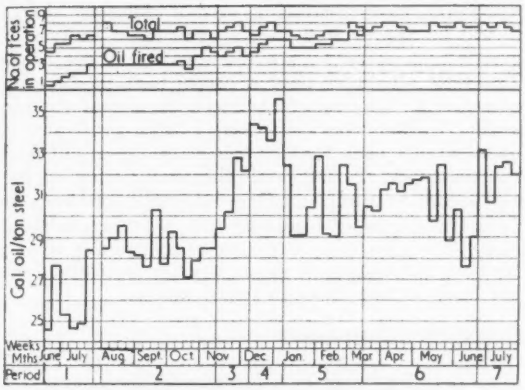

No. of fires in operation
Total
Oil fired
Gal. oil/ton steel
Weeks
Mths June July Aug Sept Oct Nov Dec Jan Feb Mar Apr May June July
Period 1 2 3 4 5 6 7

Fig. 10—Weekly oil consumption of all furnaces during period under review

As shown in Fig. 11, indicating and recording instruments are provided for oil flow, air flow through both checkers, steam flow, furnace-roof temperature (two points), flue temperature (four points, two on each end), and furnace pressure. The oil and steam flows are integrated, and the oil, air, and steam flows are recorded on a 3-point recorder. Each panel is fitted with a clock. In addition to these instruments mounted on one panel, each furnace is provided with a 4-point indicator, showing furnace draught, boiler-uptake draught, boiler-inlet draught, and boiler-outlet draught. Finally, immersion pyrometer equipment is installed on two furnaces, and is arranged so that it can ultimately be introduced as standard equipment throughout the shop. Figure 12 shows the arrangement of the panel and the furnace controls.

The advantages of standard equipment are obvious, and have been clearly demonstrated at Park Gate in the past 12 months, where it has been possible to transfer personnel from furnace to furnace with little operating difficulty. Standard equipment has also greatly assisted in the training of new furnace teams.

Instrumentation in Relation to Shop Procedure

No matter how good or how well selected the instruments are, they may ultimately fail unless they are well maintained and their indications are properly interpreted. To ensure that the fullest use is made of the equipment provided, detailed attention is paid to three main factors : (i) Instructions to furnacemen, (ii) staff observation, and (iii) compilation of furnace records.

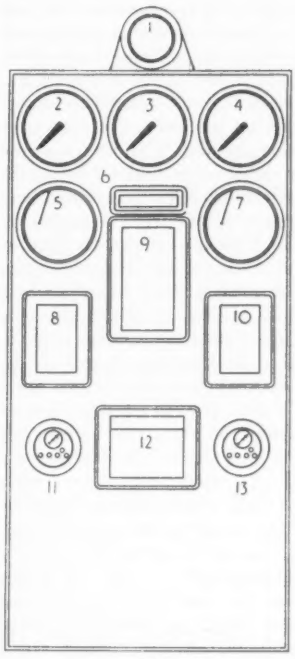
Instructions to Furnacemen—In the first place the proposed methods of operation were explained to each furnaceman, and a simple instruction card stating the main operating principles is now kept permanently on each furnace. Since it was decided to operate with constant air flow the instructions to furnace operators are greatly simplified, and a typical example is given below :

T Oil-Fired Furnace

Control Procedure

(1) The roof temperature before commencing to charge must be 1450° C.

(2) During the charging period the maximum oil flow must be kept at a dial reading of 280 gal./hr., and this should be reduced only when the roof temperature



Item	Description
1	Clock
2	Oil-flow indicator
3	Air-flow indicator
4	Steam-flow indicator
5	Roof-pressure recorder
6	Roof-temp. indicator
7	Air-flow recorder
8	Temp recorder, left-hand checkers
9	Roof-temp. recorder
10	Temp recorder, right-hand checkers
11	Oil integrator
12	Three-point recorder oil air and steam flow
13	Steam integrator

Fig. 11—Instrument panel

reaches the maximum, and scrap is not immediately available

(3) A roof temperature of 1630° C. must not be exceeded during any period of the charge

(4) On completion of charging of each run of scrap the maximum roof temperature of 1630° C. should be obtained as quickly as possible, and maintained as nearly as possible throughout the charging and melting period

(5) The oil flow should be regulated throughout the charge to maintain the roof temperature as indicated in (1), (2), and (3) above

(6) The furnace pressure should be kept constant during charging and melting at 0·05 in. W.G. by use of the damper.

(7) The oil pressure, steam pressure, and air flow should be as follows :

	Oil Pressure, lb./sq. in.	Steam Pressure, lb./sq. in.	Air Flow, 1000 cu. ft. Large Chamber	Small Chamber
Charging period	80–85	100–120	440	150
Melting period	60–65	70–75	440	150
Refining period	55–65	65–75	440	150

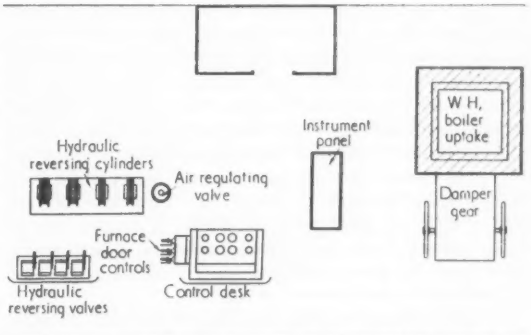


Fig. 12—Arrangement of furnace control gear

Owing to the characteristics of the burners, oil and steam pressures proved to be an unreliable guide, and as steam meters became available, oil and steam flow was substituted for pressure in the above instructions.

The requisite flows for each furnace were determined approximately before starting to charge the first heat and after heating-up was completed. Later experience indicated that very few departures had to be made from these original instructions. The procedure was of great value when furnace crews were changed or when new furnacemen had to be taught to handle oil-fired furnaces. It is not claimed that the principles followed are 100% correct nor that they have reached finality, but it is certainly true that by adopting a standard furnace technique, posting instructions at each furnace, and insisting that operators adhere to them, the number of operating variables has been greatly reduced. It is also true that in examination of records for departures from the standard technique, much has been learned about the entire process.

Staff—It was deemed advisable to place on each shift two members of the staff whose duties consist of detailed observation of the working of each furnace and investigation *at the time of the occurrence* of any deviation from normal procedure. One of these observers is trained to use the instrument panel as a guide to detecting furnace faults in checkers, flues, uptakes, boilers, etc., and to take immediate steps to deal with these occurrences. The other observer functions as an instrument mechanic whose chief duty is to keep every instrument in working order, paying particular attention to roof pyrometers.

On each furnace the roof temperature is checked against an optical pyrometer as quickly as possible after charging, which ensures that during each charge this important instrument functions under standard conditions. These regular calibrations prevent minor faults on the instrument from developing into something more serious. It is found in practice that, once the actual calibration has been made on site, no further adjustments are required to the actual instrument. The minor calibrations required ($\pm$ 10° C. max. allowance) are all made at the sighting tube. The optical pyrometers are calibrated against a tungsten-filament standard lamp.

All observers are trained in the fuel department and come under that department's jurisdiction, but collaborate with the open-hearth staff at all times. The arrangement functions excellently, particularly as regards making the furnace crews really instrument-conscious. Many of the expected difficulties do not arise because the standardization of equipment greatly simplifies maintenance and reduces the chances of furnacemen having to manage for periods without the instruments they have been pressed to use. Even relatively inexperienced observers quickly learn to interpret the records and to obviate many time-lags in detecting furnace faults. The response of the furnacemen to what was, to them, a major change in technique, was very good, and was undoubtedly influenced by the confidence they derived from this permanent maintenance service.

Furnace Records—The making of furnace records is the last, but by no means the least, important function of the instruments. With eight furnaces in operation, each producing several different charts, it will be appreciated that a systematic analysis of events is necessary to avoid delay and confusion. The shift observers play a useful part in directing attention to the major features on the charts, thereby saving endless chart-searching. The principles of operation for each furnace being already established, the observers are left with the compilation of fuel and steam consumption from integrator readings for each charge, divided initially into charging, melting, and refining periods. These are examined day by day by both the shop and works management and form the basis of immediate or future action.

Operation of Instruments

Generally speaking, after twelve months' experience, it can be said that the individual instruments and the layout as a whole have fulfilled the expectations. The amount of maintenance required has been almost negligible, a very satisfactory position considering the conditions of service on an open-hearth plant where excessive heat, dust, and vibration cannot be avoided. Two particular instruments call for some detailed consideration, namely, those required for the measurement of oil flow and of roof temperature.

The type of oil-flow meter used was selected because its design incorporated very short pressure lines carrying the differential pressure from the orifice in the oil main to the pneumatic transmitter. The latter converts the air impulse in a manometer to an electrical impulse which is transmitted to indicators and recorders. All nine installations have given excellent continuity of service, except during extremely cold weather, when those units in the most exposed positions became very sluggish and had to be corrected by bleeding-out the pressure lines. These points have now been insulated.

The meters are calibrated in turn against the storage-tank readings over weekly periods. The results obtained show that if the circulating-oil temperature is adjusted to give an oil viscosity of about 100 sec., Redwood No. 1, the meters will be within 2% error all the time and within 1% error for the majority of the time. If the correct viscosity is not maintained, errors up to 6% are recorded.

Since the quality of the atomization depends also on a uniformly maintained viscosity, particular attention is given to obtaining a uniform oil-circulating temperature. It was considered originally that bulk heating of all the circulating oil in the pump house might give more constant conditions and better control than could be obtained by heating the oil on the individual furnace branches, where the flow variations were bound to be very large. Operating results have confirmed this, no difficulty being experienced in controlling the circulating temperature to within $\pm$ 5° C.

To measure roof temperatures two fixed-focus total-radiation pyrometers, coupled to one recorder, are attached to the furnace buckstaves on each side of the tap-hole, and are placed so that the instrument is focused on the crown midway between the back springers and the longitudinal centre-line of the furnace. Experience gained with the installation described indicates that if constant and adequate

supervision is provided throughout the 24-hr., it is definitely practicable to operate the furnace with the roof temperature maintained within limits of ± 10° C. The major operational troubles on this installation have been condensation of water from compressed air, and irregularities in the nature of the mica screen. It was found that the properties of the screen could produce calibration changes of as much as 30° C. To a certain extent this point has been an advantage, since by selection of suitable screens it has been possible to balance the calibration of the two units operating on one recorder at each furnace. Another difficulty has been the splashing of the screens when hot metal was added to the bath. In every case, once the recorder and the fixed-focus units have been calibrated, on a given furnace, against the standardized optical pyrometers, no further adjustment of the recorder is necessary, all minor corrections required being carried out at the screen. This position has been achieved only by the checking of all instruments during every charge of steel, and since working at a definite roof temperature is a vital part of the furnace control, this arrangement can certainly be said to be justifiable.

HEATING-UP PROCEDURE

For preliminary heating to 600–700° C., an air-blown coke-fired heater is applied through the middle door with valves set to connect both ends of the furnace to the stack. The standard heating schedule is 10 hr. to 200° C., 16 hr. from 200° to 300° C., and 10 hr. from 300° to 700° C. In all cases the schedule is drawn out on the instrument chart beforehand and the operators work to the line drawn. Before oil is introduced into the furnace the atomizers are set at a clearance of $\frac{1}{8}$ in. and the waste-heat boiler-fan is started up to give a draught of about $\frac{3}{4}$ in. W.G. At 700° C. no difficulty is experienced in lighting the oil, but a torch is kept near the furnace, or alternatively the coke heater is kept in position until the furnace is reversed. First reversals are all made within 2 hr. of lighting the furnace, and after two or three reversals the interval is reduced to 1 hr. After 12–14 hr., $\frac{1}{2}$-hr. reversals are carried out until the furnace is ready for charging. From that time onwards strict 15-min. reversals are used. By these means an almost straight-line time/temperature relationship is followed, taken first on pyrometers in the roof and at higher temperatures, on the radiation pyrometers.

This method of heating has given a control technique far superior to that possible on producer gas, which invariably gave a rapid temperature rise for $\frac{1}{2}$ to 1 hr. after the introduction of gas, and it can be varied to suit conditions. For example, in an emergency, oil has been introduced into the furnace within 12 hr. from starting preliminary heating, and by careful regulation of the flame spalling of the roof has been avoided.

At a late stage in the heating-up period some indication of possible furnace settings is obtained by adjusting the air flow on the full available draught to give the desired furnace pressure. The oil flows for charging are calculated from the air flows obtained after making an allowance for air infiltration. It is interesting to note that very little change to these initial settings is required later. Before charging commences, atomizer clearances are reduced to $\frac{1}{16}$ in.

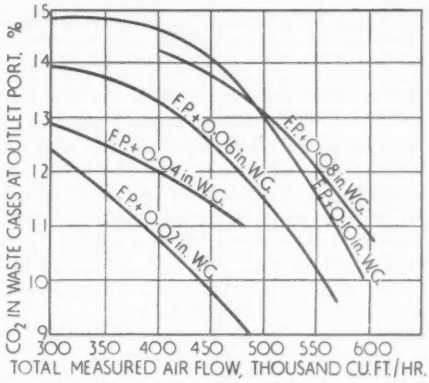


Fig. 13—Furnace pressure in relation to air flow and CO_2 in waste gases

FURNACE CONTROL

Where a furnace is not automatically controlled its subsequent performance will depend to a very large extent on the simplicity of the method of control practised, on the instructions given to staff and operatives, and on the ability to check by records that the methods put forward are being carried out. If these methods are wrong, good design can be offset and bad design can be made worse.

The control of the furnace was based on the following broad principles :

(1) Total air flow must be constant throughout the charge, its rate of flow through the two checker chambers being set according to flue-temperature indications

(2) Oil flow during charging must be at maximum, consistent with a fixed roof-temperature limit

(3) Roof temperature must not exceed a certain fixed figure throughout the charge

(4) Steam/oil ratio must be changed as soon as possible after being ' charged ' so as to give a longer radiating type of flame.

The constant air-flow method of furnace operation is certainly open to criticism on purely theoretical grounds. It has, however, been practised in America with considerable success in hot-metal shops.[1] The reasons for its adoption in the present case can best be understood by reference to Fig. 13 and Table I. Figure 13 shows the results of a series of tests made on a furnace in which the measured air flow was plotted against the CO_2 content of the outgoing gases for furnace pressures ranging from + 0·08 to + 0·02. Unfortunately, the oil flows could not be kept constant for the whole test, but the variations are not so big as to mask the principles involved.

If a line be drawn across at a reasonable waste-gas analysis, say, $12\frac{1}{2}\%$ CO_2, then the diagram clearly indicates :

(1) The same gas analysis can be obtained with widely varying, measured air flows, depending upon the furnace pressure at the time of sampling

(2) Since the ideal is to aim for the $12\frac{1}{2}\%$ CO_2 with the maximum of measured air, because all other air enters by infiltration, it is obvious from this diagram that the higher the furnace pressure the greater will be the volume of measured air in proportion to infiltrated air. The limiting value of furnace pressure

has to be set by arbitrary means, such as the degree of ' blowing-out ' around doors and the life of the lining and of the roof. The conclusion is that if the furnace pressure is worked high and constant, then the degree of air infiltration will be low and constant.

As previously indicated in Table I, the theoretical air requirements of oil fuel are almost equal to the waste-gas volume produced. If the air volume is kept constant, then variations in fuel flow will not produce very wide variation in waste-gas flow, and since furnace pressure may be considered to be the combined effect of fuel, air, and waste-gas flow, it follows that very little variation in furnace pressure or in air infiltration will take place.

Producer gas requiring 1·3 vol. of air for 1·0 vol. of gas gives 2·1 vol. of waste gas for theoretical combustion. Consequently, even with constant air flow, variations in fuel flow produce marked changes in the waste-gas volumes, furnace pressure, and air infiltration.

The practice of constant air flow is particularly applicable to oil-fired furnaces and would not be so successful on gas-fired units. The chief advantages of this method are of a more practical nature. With constant air flow it becomes possible on a hand-controlled furnace to simplify greatly the detailed instructions and thus to ease the task of interpreting and applying them. For example, if scrap supplies are freely available it is found that during the charging period an almost constant oil flow can be maintained, unless the furnace is so badly charged as to give serious flame deflection. This procedure has developed to the stage where any departure from the standard oil flow is an indication of difficulty of some kind and a matter for immediate investigation. The ideal way is to control the roof temperature during charging by frequent scrap additions, but once completely charged, the maximum roof temperature should be attained as quickly as possible. When this stage is reached, all that the furnaceman has to do is to vary the oil flow in order to maintain the maximum roof temperature and to change the steam/oil ratio to obtain the requisite flames in the different stages of the charge.

It is often suggested from a theoretical standpoint that constant air flow may perhaps at certain periods of the charge be inefficient, owing to the presence of large amounts of excess air. In practice, particularly in hot-metal plants, this supposition is not valid as, for example, A. J. Fisher[1] has shown in reporting practice at Sparrows Point.

For the purpose of actually determining at what stage changes in air flow should be made, waste-gas analyses were taken throughout several charges, which indicated that it was only during the last half-hour or so of a charge that any real change of air flow could be made with advantage.

Figure 14 shows the oil, steam, and air flows, together with the CO_2 content of the waste gases, as well as furnace pressure. The values are plotted for a complete furnace charge, using constant air flow throughout. During the last $1\frac{1}{2}$ hr. of the charge the rate of oil flow was considerably reduced. In spite of this, the CO_2 content of the waste gases does now show any appreciable change. That it does not do so is probably due to the effect of carbon boil in the bath. Owing to bad charging conditions the variations in the rate of oil flow during the charging period are rather more numerous than is usual. The furnace pressure is fairly regular apart from the charging period, and the oil-flow and steam-flow curves indicate the reductions in flow and in the changed steam/oil ratios at appropriate times.

Attempts have been made to adjust the air flow to give constant CO_2 in the waste gases by reducing the air flow towards the end of the charge. A typical result of such a trial is shown in Fig. 15, which indicates that the air flow was reduced at too early a stage, as the reduction would appear to have been

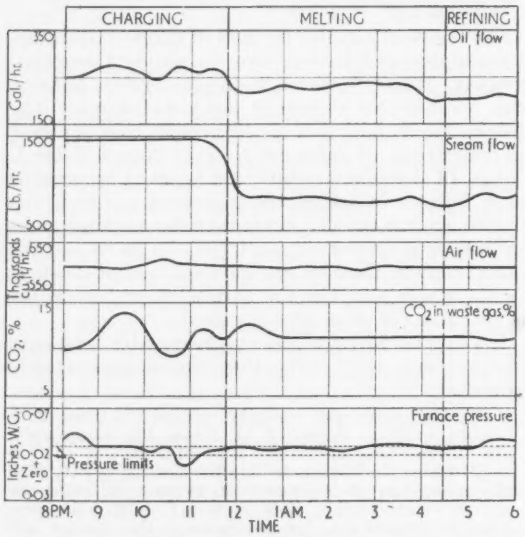


Fig. 14—Flow data for complete charge with constant air flow

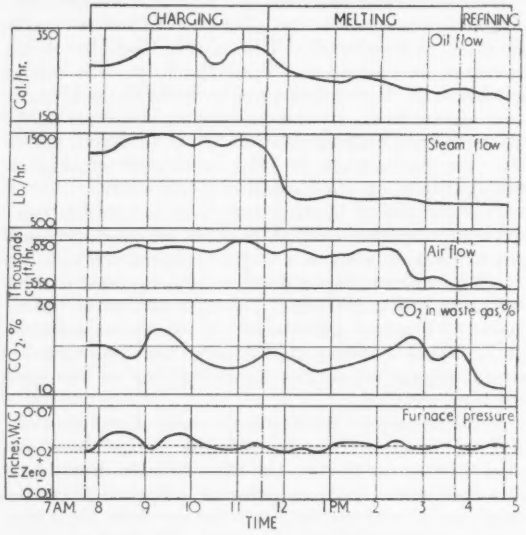


Fig. 15—Flow data for complete charge with reduced air flow during last two hours

justified only in the last 15 min. Oil-flow reductions have been introduced more gradually than are shown in Fig. 14, and during the charging period they have had to be made, due to high roof temperatures developing whilst waiting for scrap. The CO_2 curve is interesting as it shows considerably increased values due to a foaming slag.

Comparing these results, it appears that in the hot-metal process there is, contrary to expectations, little indication that constant air flow gives a large excess of air during any period of the charge.

It is also thought that when a roof begins to run, the reduction of oil flow with maintained air flow brings the crown quickly into a safe condition and so enables normal oil flows to be resumed earlier.

The proportioning of the air flow through the respective checker chambers is based as far as possible on maintaining similar time/temperature gradients in the outlet flues. In practice this procedure is found to be very useful in detecting furnace troubles. It is also found that when difficulties occur with reversing valves or checkers, the flue-temperature and air-flow records examined together give very useful indications of the location of the trouble.

AUTOMATIC FURNACE CONTROL

For some considerable time, the trend of events on this and many other plants has been towards the development of an automatically controlled furnace. The policy has been to build up by stages the experience of both staff and furnace operators. For example, the experience gained with limited equipment on the producer gas-fired furnaces showed that even with manual control, units could be worked within fairly narrow limits of furnace pressure by the careful operation of gas and air screws, and dampers. Furnace performance improved as a result of these efforts and some clearer indication was obtained of the instrumentation required for oil-fired furnaces. Confidence was established in the practice of specifying furnace-operating technique and suggesting limiting values for the various controls. The results obtained on applying this technique to oil-fired units have been encouraging and have in turn suggested, for Park Gate practice, the principles on which automatic control should be built up.

Assuming that the principle of constant air flow is retained, it is considered that the controls to be applied, in order of importance, should be as follows :

(1) Automatic roof-temperature/oil-flow control. Within this control, arrangements should be made to apply predetermined fixed oil flows during the charging period. This secondary control should be of a type which allows the automatic roof-temperature/oil-flow link to operate whenever delays in charging occur, as it is at such times that fixed oil flow becomes liable to do damage to the roof

(2) Steam/oil ratio control, which would permit the use of preset ratios at, say, three stages in the process

(3) Furnace-pressure control

(4) Automatic reversals, on a time basis.

These four controls would make the furnace fully automatic in the simplest possible way.

When considering similar applications to furnaces operating with variable air flow the position is much more complicated. The wide variations in types of controls tried out in this country and in America—with very limited success in some cases—are evidence of the existence of these complications. Nearly all these controls use at some stage the air flow measured at the valve gear. As shown in Fig. 13, the effect in the furnace of any given air flow measured at the valves will depend almost entirely on what furnace pressure is used. It is suggested that the application of automatic control would be greatly accelerated by a detailed investigation into the relationship between air flow measured at the valves, air flow measured at the inlet port, and air flow calculated from gas analyses at the outlet port, all three being determined for different furnace-pressure conditions. Since fixing the furnace pressure tends to stabilize these air-flow relationships, then an automatic damper should be the first control applied to furnaces operating on variable air flow. Without this primary control, the value of fuel/air control becomes very problematical. Furnace control based on the oxygen content of the waste gases at the outlet port is being investigated, but even this is not entirely satisfactory since it is still desirable that of the air being used for combustion the largest possible proportion should be that measured at the entering air valve in order to ensure the maximum use being made of the checker system.

DISCUSSION OF RESULTS

Analysis of Shop Operation during 57 Weeks

Figure 10 shows the weekly fuel consumption on the oil-fired furnaces from the start of the conversion, 14th June, 1947, to 24th July, 1948 ; nine furnaces were converted to oil by March, 1948. The oil required to bring new furnaces up to charging temperature is not included in these figures, but up to 13th March, 1948, when the continuous working week commenced, all oil used to heat-up furnaces after the week-end stoppage is included.

In the 57 operating weeks ending on 24th July, 1948, 235,301 tons of ingots were made, using 7,355,655 gal. of oil, *i.e.*, 31·3 gal./ton. This includes 184,192 gal. of oil which were used to heat-up new furnaces from cold. During normal production, therefore, the oil consumption was 30·5 gal./ton.

The diagram can be divided into seven distinct phases which on analysis demonstrate the influence of some of the major operating factors. Data relating to these periods are given in Table II.

Period 1 (6 weeks, ending 26th July, 1947)

During the first six weeks, the total number of gas-fired and oil-fired furnaces averaged 5·75 of which first one, then two, and at the end, three, were oil-fired.

The quality of scrap was good and the charging conditions were very favourable ; 34% of hot metal was used in the oil-fired furnaces. The oil consumption was 25·9 gal./ton, or 4·658 million B.Th.U./ton ingot.

Period 2 (14 weeks, ending 8th November, 1947)

In this period the number of furnaces working averaged 6·82, and the number of oil-fired units increased from three to five. The proportion of hot metal decreased to 31·5% of the charge and with somewhat worse charging conditions the oil consumption was 28·5 gal./ton, or 5,016,000 B.Th.U./ton ingot.

Table II
OPERATING RESULTS OBTAINED OVER A PERIOD OF 57 WEEKS

Period	Weeks	Number of Operating Units (Total for Shop), av./week	Number on Oil Available, av./week	Oil Consumption, gal./ton	Hot Metal in Oil-Fired Furnaces, %	Heat Generated, B.Th.U./ton
1	6	5·75	1·66	25·9	34	4,658,000
2	14	6·82	3·32	28·5	31·5	5,016,000
3	4	7·37	4·37	31·1	31·5	5,473,000
4	4	7·25	5·50	34·5	20·5*	6,072,000
5	10	6·85	6·75	30·3	28·7	5,338,000
6	14	7·50	7·50	30·5	30·2	5,368,000
7	5	7·60	7·60	32·1	24·0*	5,649,000

* Mixer not available, charging direct metal

Period 3 (4 weeks, ending 6th December, 1947)

During the week ending 8th November, 1947, an acute scrap shortage developed which persisted for about 8 weeks. During the first 4 weeks of this shortage 7·37 furnaces (4·37 oil-fired) were in operation, resulting in a deterioration of all charging conditions. Consequently, the oil consumption showed an increase of 2·6 gal./ton over that for the previous period when the same ratio of hot metal was used.

Period 4 (4 weeks, ending 3rd January, 1948)

During this period the shop operated on metal direct from the blast-furnace, the mixer being out of commission. Under deteriorated charging conditions similar to those obtaining during period 3, and with only 20·5% of direct hot metal, the fuel consumption averaged 34·5 gal./ton for a total of 7·25 operating furnaces, 5·50 of which were oil fired. The charging factors, *i.e.*, scrap and hot metal available in proportion to the number of units operating, became progressively worse and reached a very low level in periods 3 and 4.

Period 5 (10 weeks, ending 13th March, 1948)

In this period all the trends were reversed, the scrap supply improved, the mixer came back into service, the number of operating units was 6·85, with 5·75 oil fired, and the oil consumption was 30·3 gal./ton.

Period 6 (14 weeks, ending 19th June, 1948)

From the week ending 16th March, the shop was worked on the basis of a continuous working week, and there are indications that the oil consumptions in the first half of period 6 were slightly higher than was expected, owing to an abnormally high incidence of delays for furnace repairs. In the second half of this period there was a definite downward trend as conditions became more stable and the shop began to settle down to continuous-working conditions. The hot-metal supplies in the first half of this period were somewhat lower than during the second half.

Period 7 (5 weeks, ending 24th July, 1948)

Conditions during this period were very similar to those of period 4, in that the shop operated without the mixer, using hot metal direct from the blast-furnace. Slightly more hot metal was available in period 7 and the scrap supply was better than in period 4, but even allowing for these factors, the performance of period 7 appears to be better than that of period 4. There is always difficulty in matching blast-furnace casts with the charging of the open-hearth furnaces. In periods 4 and 7 there was therefore a very wide variation in charge constitution, ranging from 100% cold to 40% hot metal.

Factors Influencing Furnace and Shop Performance

In Figure 16 the average fuel consumptions for the seven periods have been plotted against the average proportion of hot metal in each period, irrespective of whether direct or mixer metal was used. It is interesting to note that the results for period 3 fall well out of the line of the other results.

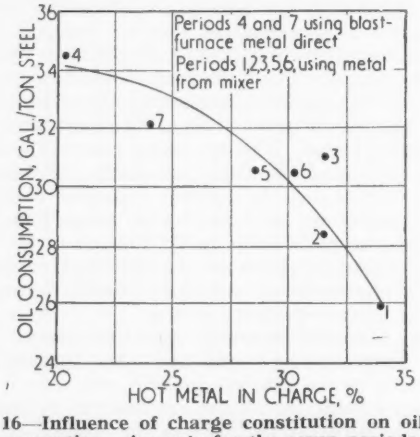


Fig. 16—Influence of charge constitution on oil consumption. Average for the seven periods

The effect of the scrap supply shortage in this period was to increase the oil consumption per ton of steel by about 2½ gal. above the normal expectation for the amount of hot metal used. The most frequently worked range for the shop as a whole was 28% to 34% of hot metal, and each 1% of additional hot metal reduced the oil consumption by about 0·9 gal. per ton of ingots.

Figure 16 is more complicated than it appears to be at first sight. Among the factors contributing to its make-up are :

Shop Layout—Assuming that a fixed amount of hot metal is available for the shop in a given week, then an increase in the number of operating units is bound to result in a decrease in the proportion of hot metal per charge and a corresponding increase in cold pig iron and scrap. As the total scrap load for the shop is increased so is the amount of work to be done by a given charging equipment, and consequently the possibilities of delays are increased. This supply factor is clearly shown in Fig. 17, where the results obtained on gas-fired furnaces for a year prior to starting the conversions are represented as tons per week per unit against the number of units working. Thus, for example, an increase of one furnace from seven to eight, yields only 414 tons to the shop total, whereas the tonnage of the individual units with good charging conditions, say, 4½ units in operation, was 770 tons/week each. This diagram gives a clear indication of supply problems in a particular shop.

The corresponding results on oil-fired furnaces are also shown, but in considering these it should be noted that certain steps were taken to improve the supply position, *e.g.*, alteration to scrap wharf, an additional shunting locomotive, and for the last two weeks of the period an additional charging machine. Although the increased outputs of oil-fired furnaces are due in part to these changes, they are largely due to the greater ability of such furnaces to recover from delays. Despite this, there is still some loss in output per unit when seven and eight units are in operation. This matter is considered so vital that a reorganization of scrap-handling facilities has been put in hand.

Type of Charge—(a) *Hot Metal*—An attempt has been made to assess the importance of the hot-metal content of the charge by examining the shop, furnace by furnace, and grouping the charges into fairly

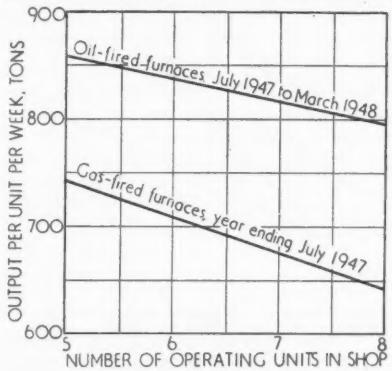


Fig. 17—Influence of number of operating units on furnace output

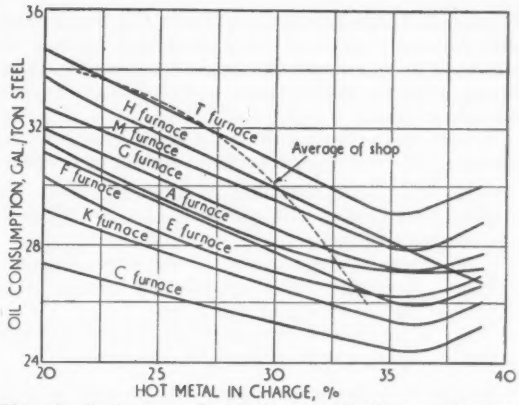


Fig. 18—Influence of charge constitution on furnace performance. Analysis of results from nine open-hearth furnaces

narrow ranges of hot-metal content. By plotting the average fuel consumptions of these groups a series of curves as shown in Fig. 18 was obtained. Considering the part of the curves covering 20–35% of hot metal, on C furnace each additional 1% of hot metal reduces the oil consumption by 0·19 gal./ton, and on T furnace by 0·37 gal./ton. The other furnaces give intermediate results. By using data taken over the full working period of each furnace, the results include both good and bad charging conditions. A small number of charges which were obviously seriously affected by other variables, such as excessive fettling, low yields due to casting-pit troubles, and 'lying-in' charges, were excluded.

When the same problem is considered on the basis of average weekly oil consumptions for the whole shop as in Fig. 16, then a low hot-metal proportion is invariably associated with difficult charging conditions, and the influence of hot-metal proportions is exaggerated as evidenced by a value of 0·9 gal./ton of oil for each 1% of hot metal. It is reasonable to conclude in this case that results are influenced both by charging conditions and by hot-metal practice.

(b) *Scrap*—On two furnaces a detailed examination was made of the charging and melting of about 120 charges ; in its first form the examination showed the curious anomaly that both the best and the worst charging times occurred when using very light scrap. The spread of charging and melting times showed some decrease when medium or very heavy scrap was used. Further investigation showed that the best times were obtained with two, three, or four furnaces on charge together. With five, six, or seven furnaces charging together, the charging and melting times varied over a very wide range. If, in these latter circumstances, light scrap was charged, the charging and melting times were considerably extended.

During this investigation it also became clear that many of the long melting times obtained were due to an endeavour to overcome charging difficulties by charging very heavy scrap in the last runs. Two other delaying factors were bundled scrap and heavy scrap, particularly when these fell in the furnace at right angles to the flame path. On several occasions, high roof temperatures have suddenly developed, and

inspection of the furnace has shown the flame being deflected by a piece of bulky scrap and running up the back lining, across the roof and down the front lining, with no visible flame in the furnace beyond the obstruction.

To achieve the best results on oil-fired furnaces during charging, the following conditions should be fulfilled:

(1) The scrap-handling equipment must be capable of dealing with the peak load, *i.e.*, all units charging together

(2) Ability to mix the types of scrap. This is a great advantage as it spreads the overall load carried by the charging equipment

(3) Where heavy scrap must be charged it should preferably be put in before the last run.

Furnace Performance—Figure 18 not only gives a measure of the influence of hot metal on practice at Park Gate, but since it includes all the charges made on each furnace it also gives a good indication of the relative furnace performance. The diagram is most accurate in the region of 25 to 35% hot metal. Below this range, the number of charges is not so large and the values are more scattered. Operating on 35% hot metal, T furnace, which has the highest oil consumption, uses an average of 29 gal./ton of steel, while C furnace, having the lowest, has an average of only 24·5 gal./ton, a difference of 4·5 gal. For the small number of 100% cold charges made, the average figures again are, T furnace 39·4 gal./ton and C furnace 31·7 gal./ton. It is clear, therefore, that with a difference of 7·7 gal./ton at 100% cold metal and 4·5 at 35% hot metal, there is a very important field to examine in the design of these furnaces since they are all operated in a similar fashion.

Furnace Hearth Proportions—The fact that furnace performance can vary over such a wide range is not surprising considering that in nearly every case the furnaces were put down as 40–50-ton units and, within the very limited ground space available, have since been increased to their present capacities by changes to the top structure, not always accompanied by similar changes to checkers and flues.

Some indication of this is obtained by examining these furnaces on the basis of McCance's classification[2] according to hearth size. On this basis only T furnace hearth is large enough for the weight charged, but on this furnace the length/breadth ratio is 3·70, as against the suggested value of 2·8 to 3·0.

It seems extremely significant that the four furnaces with the highest fuel consumption, *viz.*, T, H, M, and G, are all well outside the suggested ratio; T and M, with ratios of 3·70 and 3·27 respectively, appear to be too long for the available furnace width, while G and H, both with sloping back walls, are too short. At the other end of the scale, E, F, K, and C, as a group, are all much nearer the suggested dimensions than the T, H, M, and G group, but as previously stated all furnaces except T are, compared with McCance's rating, definitely overcharged.

It seems probable, therefore, that whilst overcharging on a well-proportioned bath may not lead to a serious increase in fuel consumption, a wrongly designed bath may give high fuel consumption even without overcharging, for example, T furnace.

Some practical indication of the importance of McCance's suggestion was obtained on G furnace. This furnace would be considered too short between the port faces, its length/breadth ratio being 2·00; furthermore, when charged with 73 tons it appears to be completely out of step with all the other furnaces on a basis of McCance's hearth-area/capacity curve. In addition to this the furnace has known draught limitations which apply mostly during charging.

On the basis of these facts the charge weight was reduced to 65 tons, and in the subsequent week the same total tonnage was obtained for a considerably lower fuel consumption.

Fuel-Burning Capacity—Since the installation of instruments, an attempt has been made to determine the maximum fuel-burning rate of each furnace. With all dampers full open, the air flow was adjusted through a wide range of settings and the furnace pressure observed for each. This gave a series of curves, typical examples being shown in Fig. 19. From previous experience the maximum furnace pressure which could be operated on each furnace was known, the air flow could be read off from the curves, and the oil flow calculated to give about 12½% CO_2 at the outlet port. This procedure really gives an approximate measure of the effect of the design of the furnace.

The furnaces near the top left-hand corner of the diagram, *i.e.*, furnaces whose design does not favour overdraughting, are those which give the best fuel consumptions.

Towards the bottom right-hand corner are a group of furnaces, similar to F, having curves which slope fairly steeply in the working range. These are considered to be prone to overdraughting or, alternatively, more suitable for the application of automatic damper control. Furnace T, in the same region, gives an almost linear relationship over an extremely wide range, and from this standpoint appears to be reasonably well designed.

This furnace factor can have a marked effect on the overall oil consumption of the department.

Because of these three major complications, shop layout, type of charge, and furnace performance, Fig. 16 should be taken as referring to this particular plant and process only. Care should also be taken in extending its implications beyond the 20 to 35% hot-metal range.

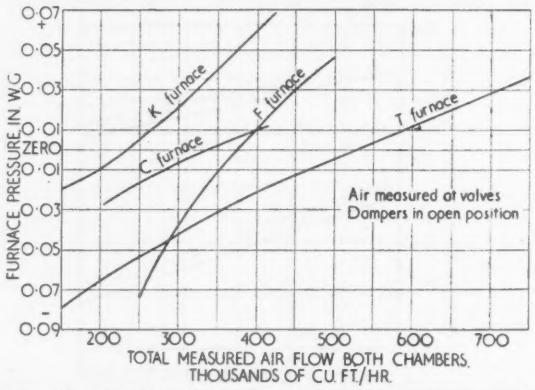


Fig. 19—Relationship between furnace pressure and air flow

It does seem reasonable to conclude, however, that the questions of proportioning and supply of hot metal, pig iron, or scrap, have a great influence on the economics of oil firing.

Roof Temperature—The furnace should be worked at the highest possible roof temperature consistent with reasonable refractory life. What this figure should be is a very controversial problem. A satisfactory answer can be found only by a process of trial and error on a given unit. The best results have been achieved when the maximum was fixed at 1640° C. It should be noted, however, that in practice whatever maximum is fixed the furnaceman generally produces a figure averaging about 10° C. below this.

It is not easy to give operating results to show the effect of varying roof temperatures, but on two furnaces on which the charging conditions were regular for a period of five weeks, different maximum roof temperatures were worked and the figures obtained indicate that in the range of 1600° to 1640° C. every 10° C. increase reduces the charging and melting times by about 0·5–0·75 hr. When the roof is worked at 1620° C. the bath temperature is low. This is indicated by skull formation in the ladle when casting most types of steel. In the case of free-cutting steels, which require heavy additions in the ladle, a roof temperature of 1640° C. is essential.

A new untouched roof has been observed to commence to run at 1680° C., but a roof which had previously been run and had a surface in roughened condition, was observed to drip slightly when the roof temperature was only 1620° C. This condition was so unusual that four checks were made with optical pyrometers at the time. It was a notable feature that in cases where slight damage had been done to roofs in the early part of campaigns, these spots invariably showed most wear when the campaign ended. This supports the theory that a new roof with uniform glaze gives the best performance eventually.

When the conversions were being considered, some concern was felt regarding what should be the correct roof height for oil-fired furnaces. Whenever possible, roofs were lifted, but eventually oil fuel was used on roofs ranging from 5 ft. 6 in. on C furnace to 7 ft. 3 in. on T furnace. It cannot be stated from available evidence that a low roof will give a shorter life than a higher one. This result is not entirely unexpected because the roof-temperature control practised tends to equalize roof life from furnace to furnace. On the other hand, all low roofs appear to be more prone to local damage outside the field covered by the radiation pyrometers. Finally, with the lower roof heights many more cases of oil-flow reductions, due to flame deflection on scrap during charging, were recorded. The balance of evidence appears to be that the higher roofs give more opportunity for carrying a higher average oil flow, and certainly allow a more uniform fuel flow during charging.

Steam/Oil Ratios—It is particularly difficult to compare figures of steam/oil ratios from plant to plant since the values reported will be influenced by several factors. The length of the charging period and, therefore, the proportion of hot metal used in the process can have a very pronounced effect. The condition of the steam and the type of burner used will also influence the final result.

Typical values of steam/oil ratios used during the charging, melting, and refining periods, for two different burners used on one furnace, are as follows :

Pounds of Steam per Gallon of Oil

	Burner *A*		Burner *C*	
Period	Total	Atomizing Steam only	Total	Atomizing Steam only
Charging	5·2	4·7	5·7	5·2
Melting	4·1	3·6	4·2	3·7
Refining	3·4	2·9	3·9	3·3

The total steam flow per gallon of oil for complete charges, including fettling, ranges from 4·0 lb. at H furnace to 4·6 lb. at T furnace.

On the original installation the steam and oil pipes and the control-valve systems were practically identical on all furnaces, and type *A* burners, with atomizer clearances set at $\frac{1}{16}$ in., were used. In the absence of any simple method of determining flame properties, the flame settings were adjusted partly by visual observation by the furnaceman and partly on the results achieved in terms of output or fuel consumption/ton steel.

It is suggested that the development of a technique for assessing flame properties, which is suitable for day-to-day operation, as distinct from complicated research equipment, is a vital necessity on any open-hearth furnace plant.

As each furnace was converted it was observed that during the charging period the requisite flame conditions were achieved only when the maximum steam flow was applied. Since this maximum flow was 950 lb. of steam per hour on each furnace, the steam/oil ratios during charging (excluding T furnace), ranged from 5 lb. of steam per gallon of oil at K furnace to 4 lb. of steam per gallon of oil at M furnace, whilst six of the furnaces were in a group using between 4·3 and 4·7 lb. of steam per gallon of oil, including the 'dead-end' steam. This high steam/oil ratio during charging had not been anticipated originally, but it agrees with the experiences reported by J. Sinclair Kerr in reporting oil-firing practice at Irlam.[3]

When T furnace was converted it was considered desirable to use oil flows of 250–300 gal./hr., and since the maximum steam flow obtainable was 950 lb./hr. only, the maximum steam/oil ratio which could be applied to this furnace was 3–3½ lb./gal. of oil. The entire steam layout was replaced, using pipe of 1½ in. dia. in place of 1 in. dia., as at the other furnaces; the maximum available steam flow was thus raised to 1600 lb./hr. Trials were made with three types of burner, *A*, *B*, and *C*. The best flame conditions during charging were observed when using *C* burner which, whilst not giving any appreciably faster time, did give lower fuel consumptions especially when steam/oil ratios were in the region of 5/1. (*See* Fig. 5).

It was intended to make trials with ratios as high as 6/1 on flows of 300 gal./hr., but this could not be achieved with any of the burners because at high oil and steam flows all three burners have characteristics indicating mutual interference between oil and steam flow. This feature was examined in detail for burner *C*, the results are shown in Fig. 20, where with the steam valve wide open, the steam flow decreased as the

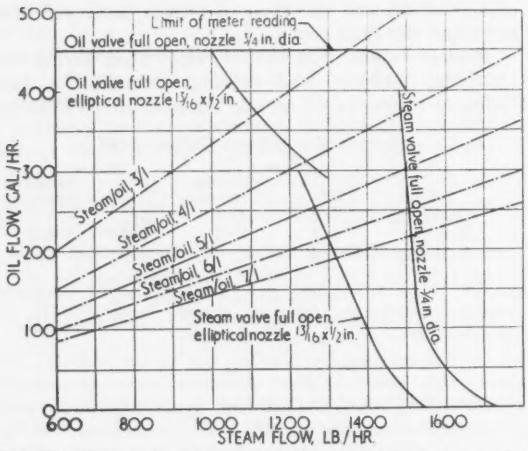


Fig. 20—Flow characteristic of type *C* burner on T furnace with two sizes of nozzle

oil flow increased. Conversely, with the oil valve wide open, the oil flow decreased as the steam flow increased.

This feature is undesirable since if at any particular setting the oil or steam flows are affected by changes in supply main pressures, then a certain amount of hunting of steam and oil flows commences which, in effect, alters the steam/oil ratio and also the flame characteristics. Eventually, the elliptical nozzle, $\frac{1}{2} \times \frac{13}{16}$ in., fitted in the tip of the burner to give some shape to the flame, was replaced by a circular nozzle of $\frac{3}{4}$ in. dia. This greatly improved the characteristics of the burner as shown in Fig. 20. Oil flows of 300 gal./hr. with steam/oil ratios of slightly more than 5/1 became possible, whilst the hunting effect was greatly reduced. No change was noted in the shape of the flame when the circular nozzle was used.

The amount of steam required to keep the dead-end burner clean has also received some attention. Originally this steam was passed through a by-pass orifice of $\frac{1}{8}$ in. dia. giving a flow of about 100 lb. of steam/hr./burner. On one furnace the orifice has been reduced to a dia. of $\frac{3}{32}$ in., and this passes 60 lb. of steam/hr./burner. No difficulty is experienced with the burners at this reduced by-pass steam flow, and it is felt that even this amount (60 lb./hr.) might be further reduced without detriment to burner operation, since deposits noted usually consist of splashes of slag adhering to the front face of the burner. Even after allowing for the by-pass steam the steam/oil ratios used are higher than was anticipated originally. This is considered to be due partly to the charging of more cold material than might be considered normal practice for this plant, and partly to the condition of the steam. It is found that there is very little superheat in the steam at the furnaces, and the installation of a superheater for the atomizing steam is considered to be a possible method of reducing the total steam consumption and at the same time improving flame characteristics.

Performance of Refractories

The consumption of refractories on an open-hearth furnace depends to a very large extent on the ability to balance the life of certain portions of the brickwork, such as ports, roof, and checkers. For example, if the useful checker life averages 25 weeks, the roof life 16 weeks and the port life 12 weeks, it would probably be more advantageous, from a production aspect, to repair the ports after 12 weeks and at the same time renew the roof, thereby obviating a further stoppage of production at 16 weeks for that purpose. Considerations of this type always influence roof life expressed in terms of weeks, but they are essential to balanced repair programmes such as described by Muir.[4]

The object of a planned repair programme is to give the maximum available furnace capacity at all times. Its success depends on an ability to forecast the life of the various parts of the furnace brickwork and the blending of repairs into a minimum number of production stoppages. The life of the various parts of the furnace will be affected by the quality of the refractories, furnace design, the process itself, and the degree of control applied to furnace operation. An economic balance between these variables must be obtained for any given plant.

The construction of the Park Gate furnaces follows orthodox lines. Chamber crowns, uptakes, port ends, and roofs are built in silica throughout. The burner block is of chrome magnesite, the straight back-walls are in metalkase magnesite tubes, and sloping back-walls are generally in chrome magnesite but are sometimes in silica. Front linings are of chrome magnesite to a height of five courses above the sill level, with the remainder in silica. Trials have been made with front linings constructed of unfired chrome magnesite bricks and gave very promising results. On the sloping back-wall furnaces, splay walls have been tried in silica, chrome magnesite, and metalkase magnesite tubes, the last-named giving the best results. Originally, the side walls at the entrance to the air port, both front and back, were built of silica, but severe erosion took place on the portion lining the air slope as far as the uptake, consequently chrome-magnesite panels were introduced at this point. The top twelve courses of the checkers are in silica brick and the remainder are in common firebrick.

Roof Life—The first two or three furnaces converted to oil firing were allowed to run until the entire roofs required replacement. On these furnaces it was observed that after 12 weeks of life wear was not severe and occurred largely on the back half of the roof. A small repair at this stage would have put the roof into good condition. From the twelfth week onwards the condition of the roof deteriorated rapidly, and the extent of the repair required increased in proportion until at about 16 weeks the entire roof had to be replaced. It was decided, therefore, that the furnace repairs should be based on a small roof repair at 12 weeks, with a new roof at about 25 weeks. Owing to difficulties with checker chambers and the necessity to blend the conversion programme with normal repairs, it has not yet been possible to implement fully this policy, but for the period from March to August, 1948, during which all furnaces were operating on oil fuel, the indications are that this basis of 25 weeks' roof life, with a patch at 12 weeks, will prove quite satisfactory from the point of view of planned repairs.

The following data on roof life cover the entire year during the first part of which the furnaces were shut down during weekends, whilst from 13th March, 1948, the continuous working week was operated:

Furnace	Life before Patching, weeks	Total Roof Life, weeks
M	16, 14	28, 30
K	11	23, 8*
A	16, 11, 14	16, 21, 18*
C	14, 8†	20, 20
E	14	20, 11, 12
F	Not patched	11, 14
G	,, ,,	18, 13, 12*
H	13	18*
T	12, 12	18, 12*

* Life incomplete at time of writing
† Mechanical damage to roof during charging in the eighth week

The following figures are a comparison of roof performances on gas-fired and oil-fired furnaces, in terms of production under a given roof:

Furnace	Gas Fired. Steel Per Roof, tons	Oil Fired. Steel Per Roof, tons
M	10,552	14,198
K	10,051	12,174
A	8797	10,610
C	9455	11,320
E	8566	10,491
F	8605	7535
G	9283	10,826
H	8900	10,109
T	8864	12,111

For this purpose, all patching has been taken into account by estimating the patch area as a fraction of a complete roof. Thus, for example, with a new roof at the beginning of a campaign, and a half-roof repair during the campaign, the total tonnage obtained in that campaign is multiplied by 0·66 to obtain the steel production per roof. The figures for gas-fired furnaces were obtained over a period of $2\frac{1}{2}$ years immediately before the conversion. For the oil-fired furnaces the period is shorter (15 months) and might not be considered long enough to assess roof life. It does seem significant, however, that within this period, with the exception of F furnace, output obtained per roof has definitely increased.

Another important feature which does not appear in this comparison is the greater regularity of performance when using oil fuel. The previous practice on producer gas was notable for its exceedingly wide variations in roof life, a factor which ultimately caused loss in output due to inability to forecast repairs accurately. This narrowing down of the range of performance is definitely advantageous, and has been attributed to closer reproduction of furnace operation, cast by cast, a direct result of instrumentation and its method of application.

Checker Life—Another major factor in determining the production performance of open-hearth furnaces is checker life. This appears to be related to the relative efficiencies of the slag pockets on the furnaces. For example, T furnace has satisfactory slag pockets, those on K and M are not so well designed, whilst A, C, E, F, G, and H have been modified but are not really satisfactory. At the present time T furnace checkers have been in operation 30 weeks and are planned to be renewed at 34 weeks. Furnace M checkers were replaced after operating for 38 weeks, 10 of which were on producer gas. The furnaces with less satisfactory slag pockets gave shorter checker lives. It is not practicable on this plant to clean checkers during a campaign, so that the partial replacement of checkers at intervals does not offer any great advantages, and checker lives of 35–40 weeks are considered satisfactory. No serious dust deposition has taken place in the chambers, but the upper courses of bricks have fused and distorted giving a considerable reduction in the area of the passages. There has, however, been an increase in the quantity of dust deposited in flues and valves.

Burner Blocks—The performance of this part of the furnace which is built in chrome-magnesite brick has been satisfactory. The policy of making the water-cooling pipes at the tip of the burner independent of the brickwork has helped considerably in this connection. Burst water pipes have been withdrawn and replaced without interfering with the construction of the block. On a few occasions flame deflection has been caused by typical chrome-magnesite brick growths falling on to the bank immediately in front of the burner tip.

Front and Back Linings—Oil firing has given better results generally in terms of tons per lining than did producer gas. This position would have been much better but for one factor in the process which seemed to come in cycles, namely foaming and lifting slags. The incidence of slags which lift and foam, often for periods of up to two hours, is much greater when using oil fuel. These slags sometimes cause serious damage to linings which are otherwise in good condition. The front linings seem to suffer most damage and of the various expedients tried to reduce this, the use of unfired chrome-magnesite bricks in the lining is most successful. A considerable amount of work is being conducted into the causes of slag behaviour of this type, as serious losses in production are suffered due to lining damage as well as to having to reduce the rate of firing during periods of foaming.

It is also felt that the Park Gate furnaces are subject to abnormal flame erosion by reason of their very narrow construction, the narrowest being 10 ft. 6 in. and the widest 12 ft. 6 in. between linings.

Acknowledgments

The authors would like to record their appreciation of the assistance received from those firms which, having made conversions, granted them permission to inspect the installations and thus gave them the benefit of their experience; and to all members of the Park Gate organization who co-operated, both during the conversion period and in the subsequent investigations, they offer their sincere thanks.

For permission to publish this paper they wish to express their thanks to the Directors of the Park Gate Iron and Steel Co., Ltd., particularly to Mr. C. H. T. Williams, Managing Director, for his encouragement.

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Grain Growth in Silicon–Chromium Valve Steel

By H. Allsop, A.Met., F.I.M., and P. W. Bygate, A.Met.

SYNOPSIS

The occurrence of severe grain growth in silicon–chromium valve steels, conforming in composition to B.S. En 52, and to which attention has been previously drawn, has been investigated.

It is shown that grain growth of the order noted occurs as a result of reheating critically strained material to sub-critical temperatures. If the material is in the ferritic condition at the time of straining, the degree of coarsening is influenced by the structure, the most severe growth resulting when the steel is strained in the hardened and tempered state. The temperature of the material when strained is not important, provided the ferritic condition is maintained. Alternatively, grain growth of a similar order may result from strain during hot forging if, at the time of straining, the temperature does not exceed approximately 750° C., in which case the material may be austenitic, or have transformed to widely different products. The severity of the grain growth resulting from either condition of straining is markedly influenced by the hardening temperature in the case of material strained in the hardened and tempered condition, or the initial temperature in the case of material strained during hot forging. High hardening or forging temperatures notably reduce the tendency to coarsen on reheating the strained material. Coarsened material is notch-brittle at elevated temperatures.

The tendency to coarsen increases with increasing silicon content, within the limits of B.S. En 52. The temperature necessary to effect refinement of coarsened material also increases with increasing silicon and chromium.

ATTENTION has been drawn by Hodgson* to the occurrence of abnormally large grains in silicon–chromium steel valves, complying in composition and heat-treatment with the relevant specifications D.T.D. 13B, En 52, and V. 24. The same author suggests that the grain growth is due to the use of too low a hardening temperature following critical strain induced in prior manipulation, and shows that, if the hardening temperature is raised, *e.g.*, from 950° C. to 1050° C., previously coarsened material is effectively refined. The examples shown are so impressive (especially when it is considered that the heating for hardening of such small parts as internal combustion engine valves is not likely to be prolonged), that some investigation of the phenomenon seemed to be worth while.

The examples shown by Hodgson were on valve heads on which it is considered impossible to estimate the strain induced on the affected zones. It was therefore decided to attempt to assess the amount of strain necessary to produce grain growth on reheating, and the reheating temperature at which grain growth occurs most readily.

STRAIN NECESSARY TO PRODUCE GRAIN GROWTH

The tensile test offers a ready means of producing strained material, and if a test-piece is broken, a range of strain is produced, varying from the maximum obtainable near the fracture, at the test temperature, to a minimum at the ends of the gauge length. Tensile test-pieces were therefore prepared and, since the amount of strain necessary was not known, they were prepared from hardened and tempered bars so as to ensure the greatest capacity for cold deformation.

The material used throughout the earlier part of the investigation had the following composition :

C, %	Si, %	Mn, %	Cr, %	Ni, %
0·46	3·74	0·53	8·0	0·20

Pieces of this material were hardened and tempered (O.H. 1025–1050° C., T. 850° C.) and machined to 3-in. × 0·564-in. dia. tensile test-pieces. These pieces gave maximum stress values ranging from 61·3 to 62·7 tons/sq. in., with elongation values of 25% to 27·5%.

Halves of the broken pieces were reheated for 30 min. at 700° C. and at intervals up to 940° C., the latter being just below the minimum hardening temperature permitted by the relevant specifications for this type of steel.† The reheated pieces were sectioned along their axes, polished, and etched in a solution‡ of 50% hydrochloric acid, 5% chromic acid, and 45% water. No grain growth was apparent on the piece reheated at 700° C. The etched sections of the other test-pieces, *i.e.*, reheated at 750° C. and higher, are shown in Fig. 1. All the pieces show grain growth in those portions strained more than a certain small amount. The change from normal to coarsened material occurs fairly abruptly in the piece reheated at 750° C., and becomes more abrupt as the reheating temperature is raised. In the pieces reheated at 750° C. and at 800° C., there is little evidence of preferential grain growth to indicate a critical degree of strain ; but reheating at 925° C. and at 940° C., clearly shows that maximum grain growth is associated with a small degree of strain, and reheating at these temperatures shows a very abrupt change in crystal size between under-strained and critically strained material. Although not very clearly seen in Fig. 1, differential grain growth is visible in the piece reheated at 850° C., as shown in Fig. 2, which illustrates the transition zone of the piece. Figure 3 shows the transition zone of the piece reheated at 940° C., in which differential grain growth is clearly visible.

Manuscript received 20th December, 1948.

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* C. C. Hodgson, *Metallurgia*, 1946, vol. 34, No. 200, June, pp. 69–76.

† The hardening temperature range is given as 950–1050° C., in B.S. 970 : 1942, but is amended to 1000–1050° C., in B.S. 970 : 1947.

‡ Private communication from Mr. C. C. Hodgson.

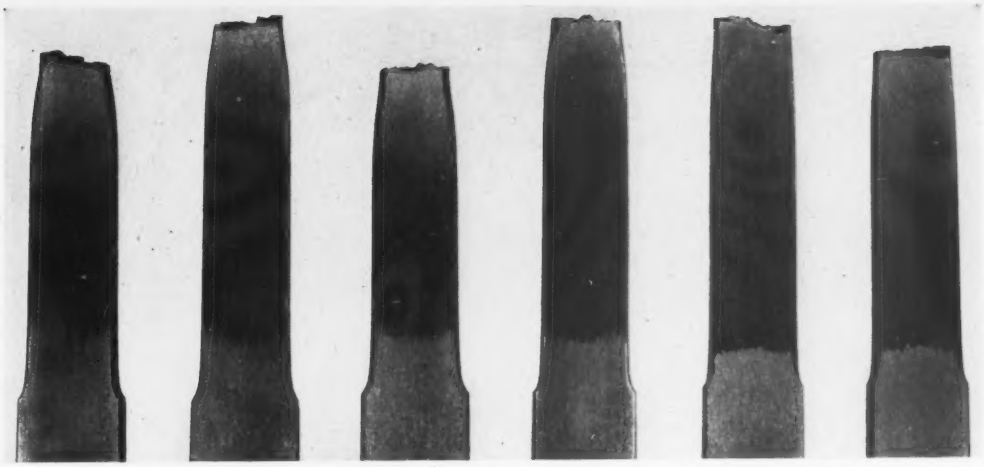

Fig. 1—Grain growth in broken tensile test-pieces reheated to various temperatures (° C.) for 30 min. Natural size

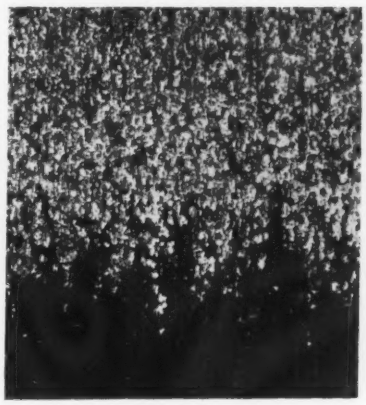

Fig. 2—Transition zone of the tensile test-piece reheated to 850° C. (see Fig. 1). × 10

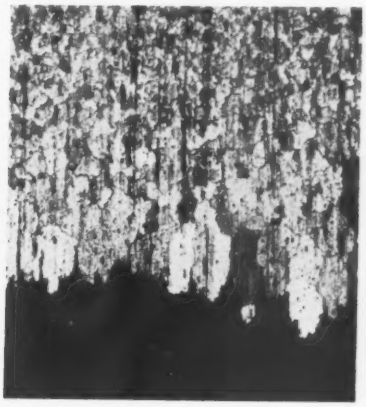

Fig. 3—Transition zone of the tensile test-piece reheated to 940° C. (see Fig. 1). × 10

Fig. 2 was taken by oblique lighting and the coarsened grains appear dark ; Figs. 2 and 3 were taken by vertical illumination and the coarsened grains appear light compared with the normal areas. The method of illumination is governed by the magnification used.

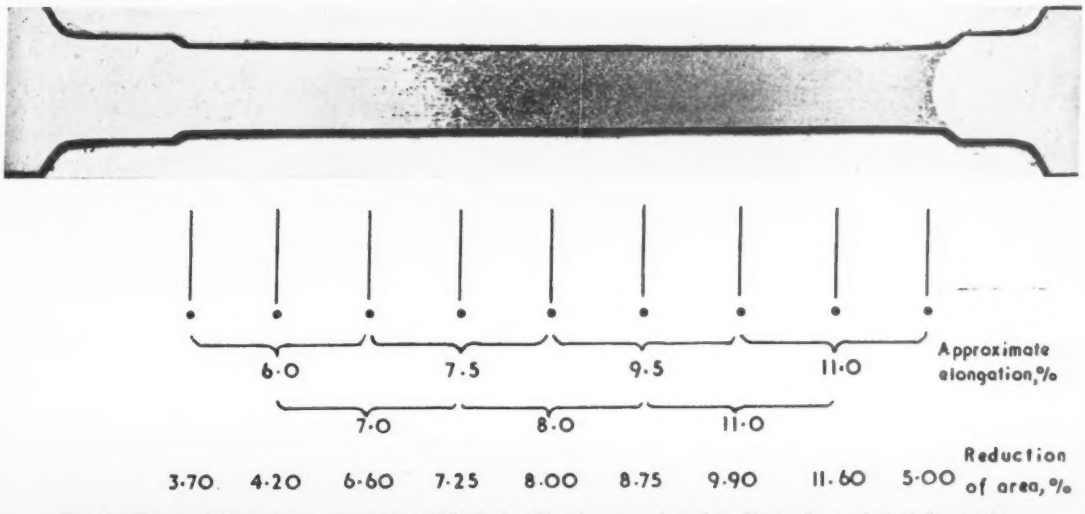

Fig. 4—Tapered test-piece reheated to 925° C. for 30 min. showing the effect of varying deformation on grain growth. Natural size

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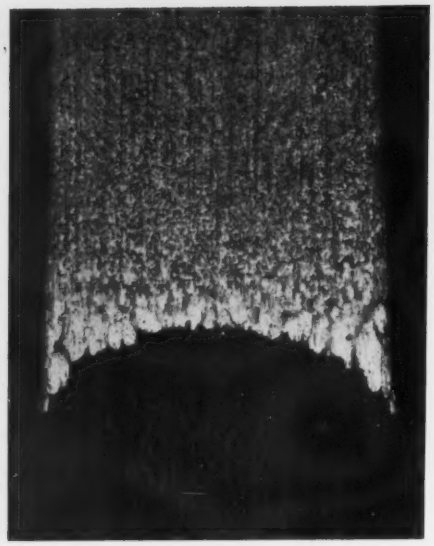


Fig. 5—Grain growth associated with the steep strain gradient (see Fig. 4) × 4

Fig. 6—Grain growth resulting from 7 to 8 per cent. elongation (see Fig. 4) × 4

Fig. 7—Grain growth in a parallel test-piece elongated 8 per cent., reheated to 925° C. Natural size

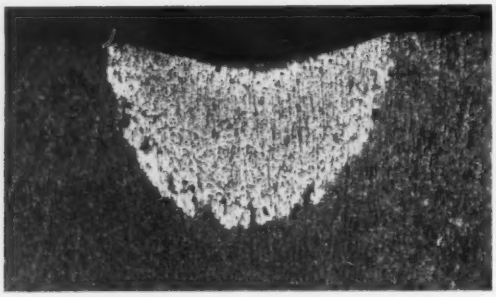


Fig. 8—Hardened and tempered material indented at room temperature, reheated to 900° C. × 10

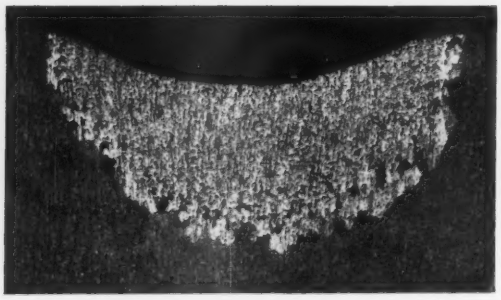


Fig. 9—Hardened and tempered material indented at 900° C., reheated to 900° C. × 10

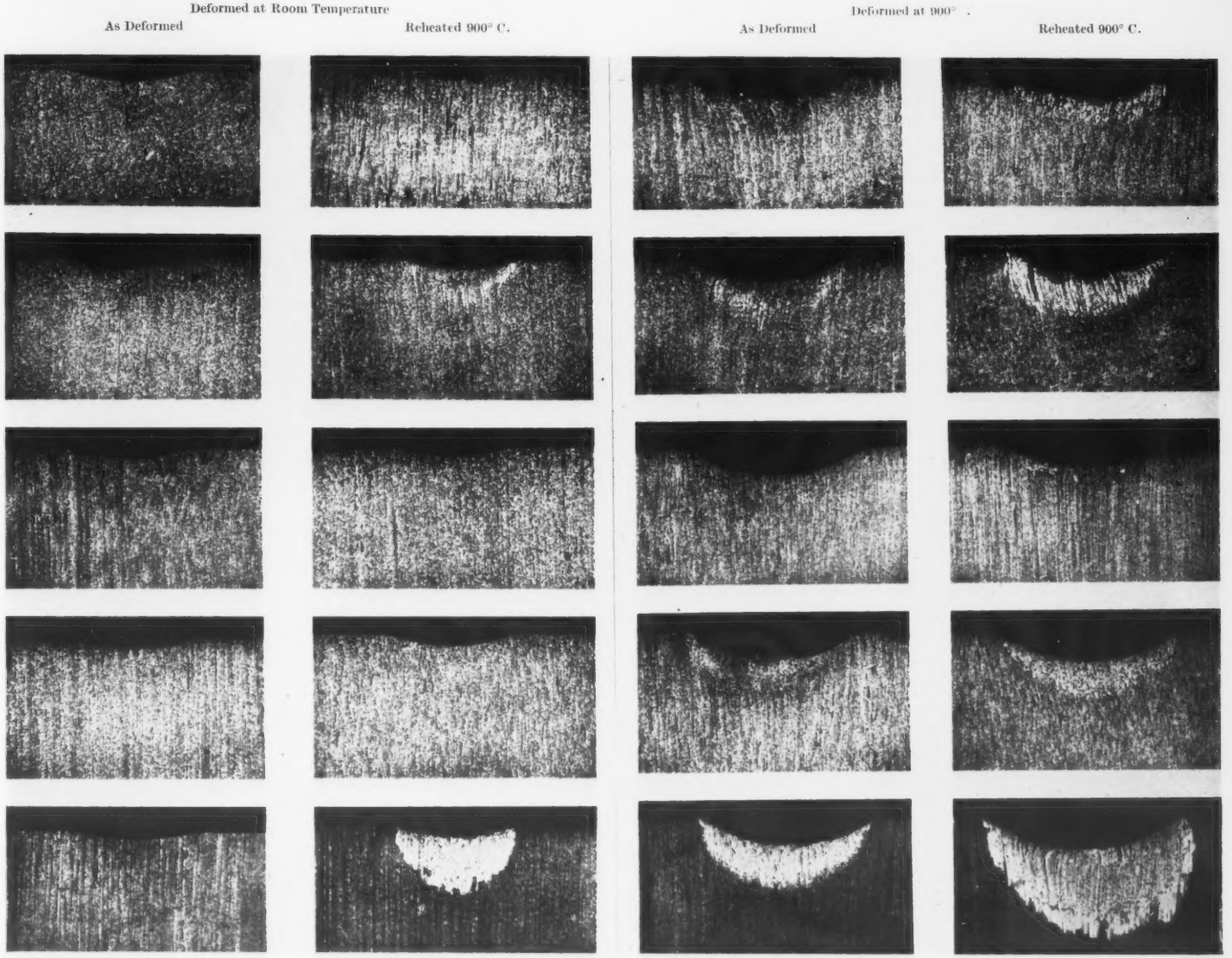


Fig. 10—Series of indented specimens showing the effect of prior structure on susceptibility to grain growth × 6

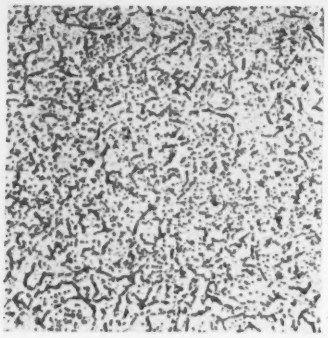


Fig. 11—Microstructure of material normalized 1050° C., tempered 900° C. × 500

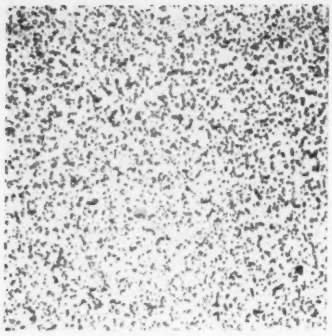
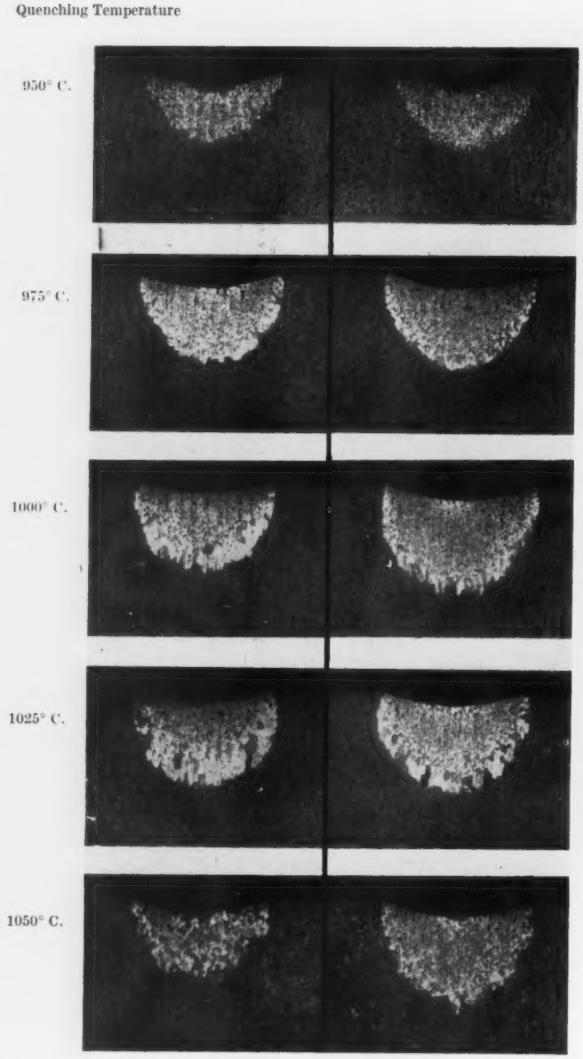


Fig. 12—Microstructure of material oil-hardened 1050° C., tempered 900° C. × 500



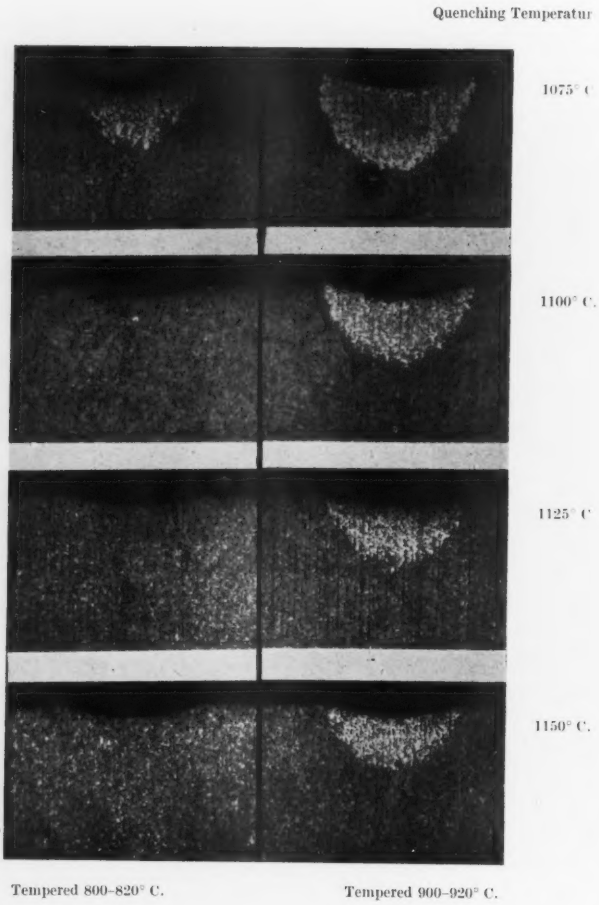


Fig. 13—The effect of variation of hardening and tempering temperatures on sensitivity to grain growth. Specimens indented cold and reheated to 900-925° C. × 5

The coarseness of the grain following critical strain is directly related to the reheating temperature, as shown by the various pieces in Fig. 1 and by comparing Figs. 2 and 3, but the grain growth in the portions strained more than the critical amount, is not significantly influenced by the reheating temperature.

The limit of the coarsened zone in the various pieces in Fig. 1, suggests that, as the reheating temperature rises, the strain required to produce maximum grain growth decreases. The test-pieces had not, of course, deformed perfectly similarly, but careful measurement of the diameters, at the limit of the coarsened area, does appear to confirm the above effect, as the following data show :

Reheating temperature, °C	Approx. area reduction at point of max. grain growth, %
750	11·0
800	10·3
850	9·8
900	8·4
925	7·6
940	7·5

In order to obtain a better measure of the critical strain, a tensile test-piece was prepared from hardened and tempered bar as previously, except that the diameter of the gauge length was reduced from 0·564 to 0·545 in. over a length of 4 in. The gauge length was marked off at $\frac{1}{2}$-in. intervals, and the piece was loaded until the centre 3 in. of the gauge length showed 9% elongation, after which it was reheated (925° C.), sectioned, and etched as before. Details of the varying deformation of the test-piece along the gauge length, together with the appearance of the etched section, are shown in Fig. 4. It will be seen that maximum grain growth occurs at an elongation of 7·5%, corresponding to a reduction of area of 7·2%. Portions of the test-piece, showing the limits of the coarsened zone, are illustrated in Figs. 5 and 6. In the former, where the strain gradient is very steep, the change from normal to coarsened grains is very abrupt, whereas, in the latter, the transition zone appears gradual; but it should be noted that, over the range showing very coarse grains, the variation in reduction of area is something less than 1%. It is again apparent that strain in excess of the critical amount induces grain growth to an extent notably less than the critical strain. Figure 7 shows a section through a parallel test-piece, hardened and tempered, strained (elongation, 8·0% ; reduction of area, 7·4%), reheated, and etched as described earlier.

It is evident, from the work so far described, that this material will coarsen to a remarkable extent as a result of sub-critical heating, following critical cold work or strain. The conditions under which the coarsened material has been produced differ in several respects, *e.g.*, temperature of deformation, prior condition, etc., from those likely to obtain in hot working, *i.e.*, valve forging. They do not necessarily explain, therefore, the occurrence of coarse grains in hot-forged valves.

EFFECT OF PRIOR CONDITION ON GRAIN GROWTH

The tensile test is not a convenient method of providing strained material at elevated temperatures, and since the critical amount of deformation appears to be small, it was considered that the necessary condition of strain could be obtained by local indentations, as, for example, by a Brinell impression or, at elevated temperatures, a round-nosed punch. The suitability of this method of producing grain growth is shown in Fig. 8, which shows a section through a Brinell impression, made on a hardened and tempered sample, reheated at 900° C., after indenting cold. Figure 9 shows a section through a punched impression made at 900° C. on a previously hardened and tempered sample. This piece was finally reheated at 900° C., after making the impression. The samples also show that the straining temperature is not of particular significance providing, of course, that it is sub-critical.

Although no difficulty was experienced in producing coarsened material on hardened and tempered samples by the methods previously described, it was found that a similar procedure produced no grain growth on ' as-rolled ' samples, thereby indicating that the prior structure was an important factor. The effect of the prior structure on grain growth has been examined on samples in different conditions of heat-treatment, deformed cold by Brinell impression, and at 900° C. by punch. Duplicate sets of samples were prepared, of which one set was reheated at 900° C. before sectioning. The details of the heat-treatments of the individual sample, the temperature of deformation, etc., are given in Fig. 10, which shows etched sections through the various impressions. It is evident that the sensitivity of the material to grain growth varies with its heat-treatment conditions, but is most pronounced in the hardened and tempered state ; in fact it is only in this state that grains comparable with those shown by Hodgson are produced. Examination of the microstructure of the as-rolled and tempered, normalized and tempered, and hardened and tempered, samples shows clearly that the carbide distribution and form is most uniform in the last condition, but the difference in grain growth susceptibility appears quite disproportionate to the difference in microstructure. Typical microstructures of the normalized and tempered, and oil-hardened and tempered material are shown in Figs. 11 and 12, respectively. It is also shown in Fig. 10 that, if hardened and tempered material is deformed at 900° C., some grain growth will occur without subsequent reheating, no doubt owing to the tempering effect of the hot sample itself, but the grain growth is notably accentuated, both in extent and grain size developed, by cooling and reheating. The normalizing and hardening temperature used in the series was 1050° C. It is known that quenching this type of material from high temperatures, *e.g.*, 1100–1150° C., frequently results in rather lower hardness, probably because of the retention of a small amount of austenite, and it was thought that variations in the hardening temperature might possibly influence the sensitivity to coarsening. At the same time, comparison was made of the effect of tempering at 800 and 900° C.

Duplicate samples were oil-quenched from 950° C., and at intervals of 25° up to and including 1150° C. One set of samples was tempered at 800–820° C., and

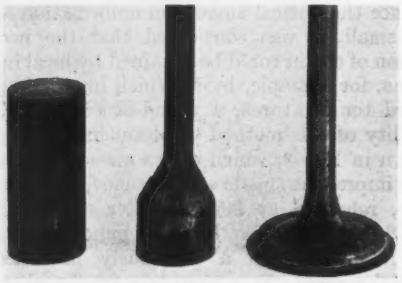


Fig. 14—Stages in valve extrusion

the other at 900–920° C. All the samples were indented cold, by Brinell impression, and reheated at 900–925° C. The samples of both series, sectioned through the impressions, are shown in Fig. 13. Independent of the tempering temperature, grain growth occurs most markedly in the samples hardened from 1000° C., 1025° C., and 1050° C., with evidence of a preference in the 1025° C. pieces. The hardening range from which grain growth is produced is shorter in the series tempered at 800–820° C. than in that tempered at 900–920° C., but it is clear that there is an optimum hardening range in both series, and grain growth does not progressively increase as a consequence of increasing hardening temperature.

OCCURRENCE OF GRAIN GROWTH IN HOT WORKING

It has been shown that the occurrence of severely coarsened grains results most readily from the hardened and tempered condition, and that the coarsening is also influenced by the hardening temperature. Consequently, to account for the occurrence of coarse grains in forged valves, it seems necessary to visualize that circumstances may arise in the hot forming which will virtually produce the hardened and tempered state. Valves made by extrusion are generally produced in two stages, without intermediate reheating, as shown in Fig. 14. By the first stage, the stem is extruded from a slug of stock bar diameter, and, at the second stage, the head is upset. These stages are known in the trade as ' extruding ' and ' coining,' respectively. That portion of the valve forming the radius under the head is likely to be pressed into closest contact with the bottom dies at both stages, and finished (*i.e.*, coined) valves frequently do show ' cold ' areas under the head. It is conceivable that the valves may be ' die quenched ' thereby in those portions, and it is significant that it is in those positions that the coarse grains are generally observed. It is reasonable to believe, therefore, that the hardened and tempered condition, or a condition sufficiently approximating to it, can be produced under a valve head, by die quenching some portion of the skin of the valve in the first dies. This portion may be reheated (tempered) by the hot body of the valve, and strained in the second dies.

The conditions postulated previously as occurring in forging practice can be reasonably duplicated by quenching small samples from the hardening (forging) temperature into liquid baths held at various lower temperatures. The quenched pieces may then be immediately reheated to 900° C.

To ensure regularity in straining, the samples were deformed mechanically by means of a Charpy-type impact machine, and the initial energy of the blow, determined by trial and error, was that which produced maximum grain growth in normally hardened and tempered specimens deformed at 900° C. The energy of the blow so determined was kept constant throughout the series. The samples used were standard Charpy pieces 10 mm. square (un-notched), machined from as-rolled bar. Three initial temperatures were used, covering the range 1020–1160° C., which was considered to cover adequately the temperature range likely to obtain in forging practice. From each initial temperature, individual pieces were quenched down to temperatures varying from 20 to 900° C. After immersion for 30 sec., in all cases, they were immediately transferred to a furnace at 900° C., until they attained that temperature, then rapidly put into the Charpy machine, deformed, and allowed to air cool. Following this, they were reheated for 30 min. at 900–925° C., air-cooled, sectioned, and etched. In addition, one piece was deformed at each of the three initial temperatures used. Etched sections through the bends, in which the effect of initial temperature can be clearly seen, are shown in Fig. 15. The difference between the 1020–1040° C. series, and the two higher-temperature series, is very striking. In the latter two series there is slight superficial grain growth on some of the samples, largely, but not entirely, confined to the low-temperature quenched pieces.

EFFECT OF GRAIN SIZE ON TOUGHNESS

Silicon–chromium valve steel of En 52 type, as normally hardened and tempered for use, does not usually give high impact values at atmospheric temperature, but possesses satisfactory toughness at the temperatures at which such valves usually operate. A comparison has been made, therefore, of the impact values of normal and coarsened material at ordinary temperatures and at an elevated temperature. The normal material was hardened and tempered in the ordinary way, and the coarsened material was obtained by straining, by tension, previously hardened and tempered material. The results are as follows :

Grain size	Testing temp. 20° C.	750° C.
Fine	3, 3, 3 ft.lb.	95 ft.lb. approx.
Coarse	1, 1, 1 ft.lb.	8 ft.lb. approx., broken

The fractures of the pieces tested at 20° C., and the bent and broken pieces, respectively fine and coarse grained, tested at 750° C., are shown in Fig. 16. The crystal facets of the coarsened pieces, tested at 750° C., are dulled by a temper colour film, but are otherwise exactly like the corresponding pieces broken at room temperature.

REFINEMENT AND RE-SOLUTION

Small portions of material coarsened by tension, as described earlier, were reheated to varying temperatures, and the commencement and progress of refinement were followed by means of microsections. Figures 17 and 18 show a typical microstructure of

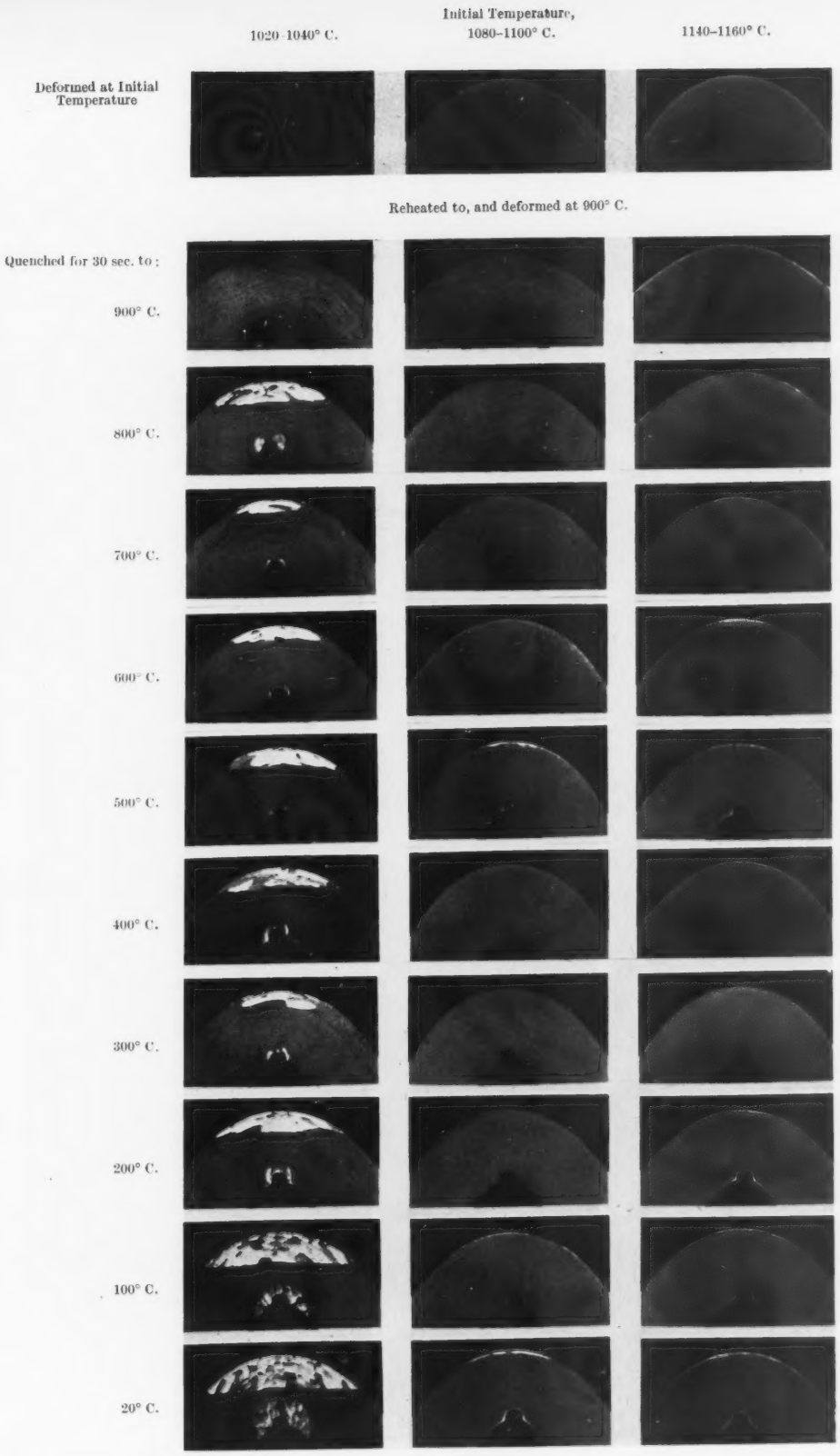


Fig. 15—The effect of initial temperature on susceptibility to grain growth. × 3

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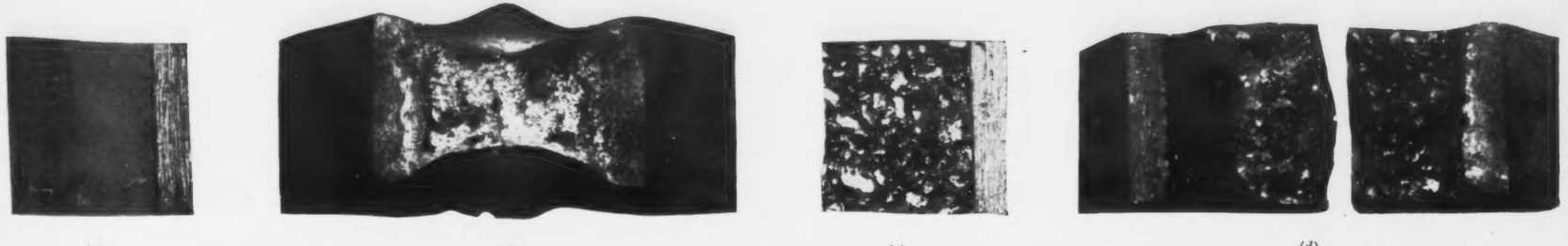

(a) (b) (c) (d)

Fig. 16—Fractures on normal and coarsened impact specimens (*a*) and (*b*), hardened and tempered ; impact test (*a*) at 20° C., (*b*) at 750° C. ; (*c*) and (*d*) hardened, tempered and coarsened ; impact test (*c*) at 20° C., (*d*) at 750° C. × 3

Fig. 17—A.C. 925° C. × 125

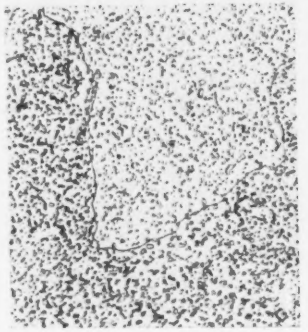

Fig. 18—A.C. 925° C. × 500

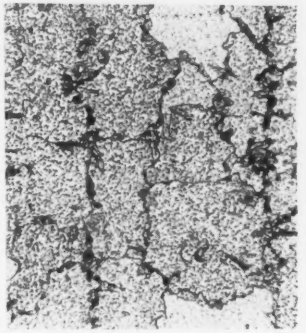

Fig. 19—A.C. 975° C. × 125

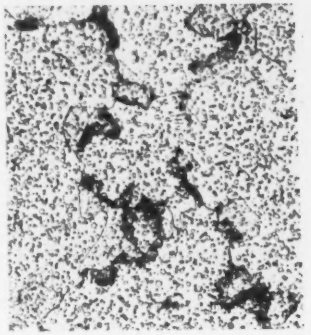

Fig. 20—A.C. 975° C. × 500

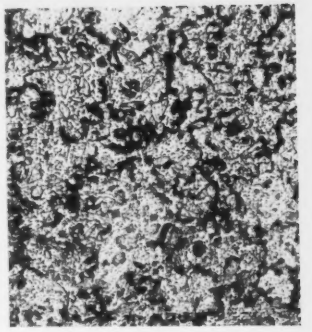

Fig. 21—A.C. 1000° C. × 125

Fig. 22—A.C. 1000° C. × 500

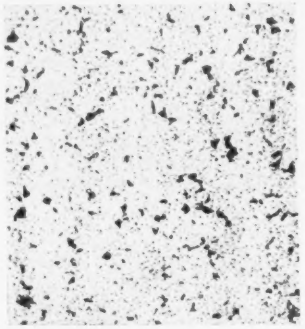

Fig. 23—A.C. 1025° C. × 125

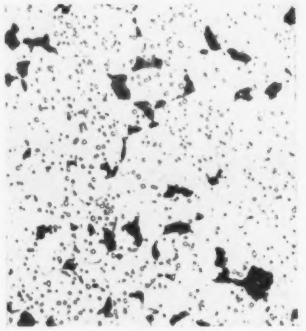

Fig. 24—A.C. 1025° C. × 500

Fig. 25—A.C. 1050° C. × 125

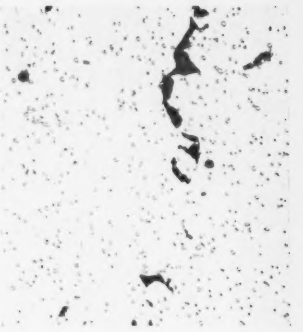

Fig. 26—A.C. 1050° C. × 500

Figs. 17 to 26—Microstructure of critically strained material reheated at 925° C. for 30 min., air-cooled from varying temperatures

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Figs. 17 to 26—Microstructure of critically strained material reheated at 925° C. for 30 min., air-cooled from varying temperatures

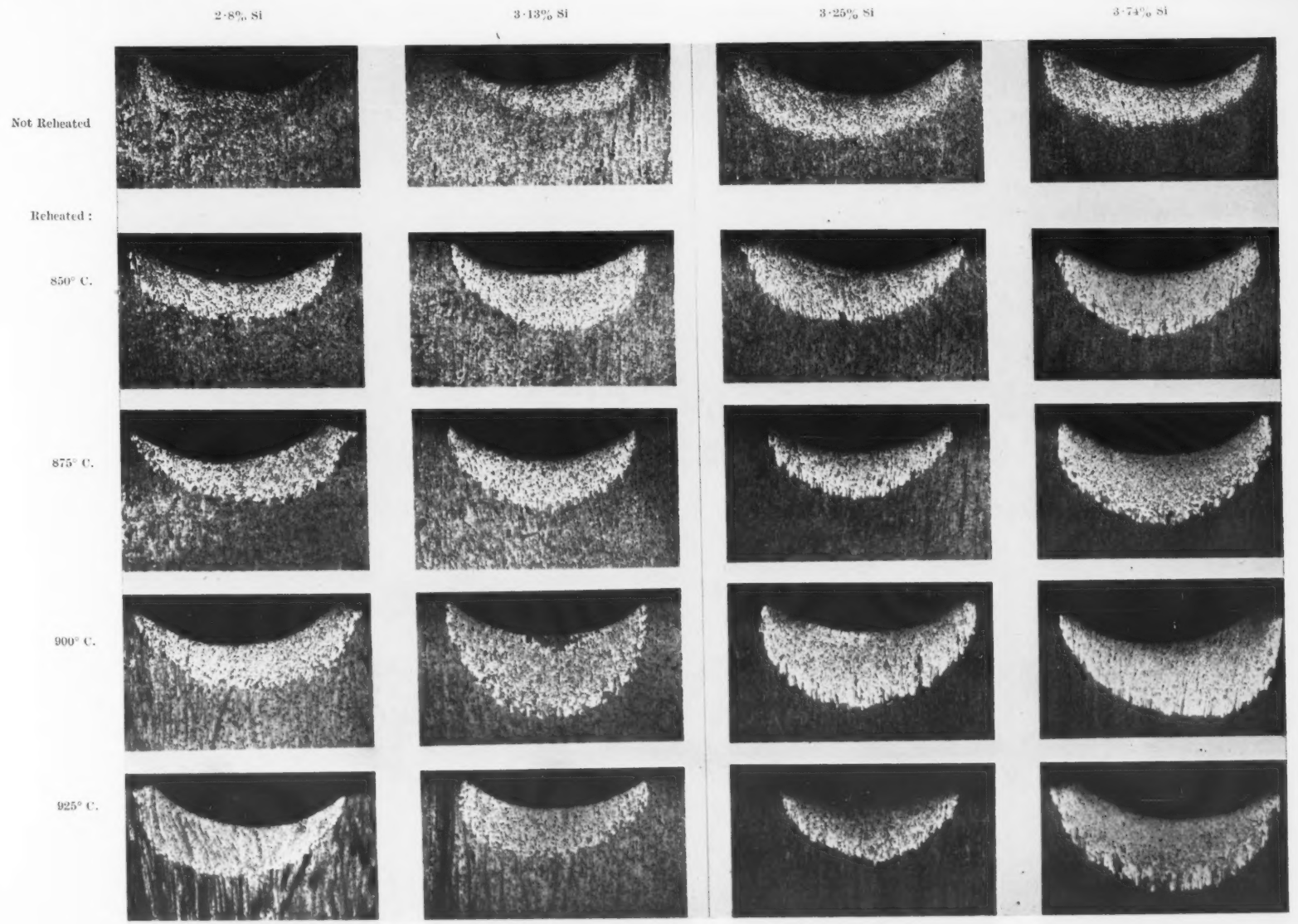

Fig. 27a—Series of hot-punched specimens showing the effect of varying silicon content on grain growth and refinement × 6

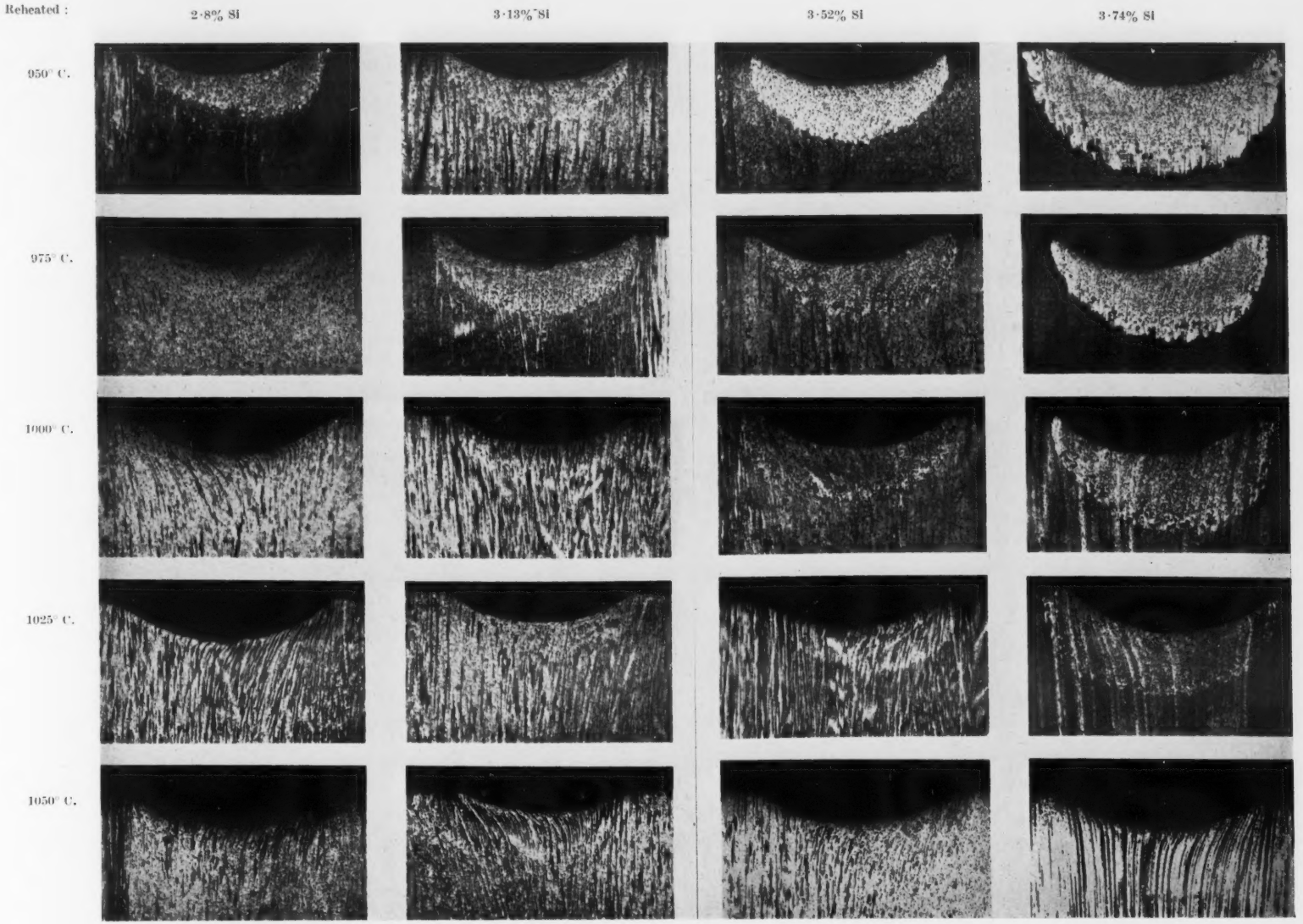

Fig. 27b—Series of hot-punched specimens showing the effect of varying silicon content on grain growth and refinement × 6

Fig. 27b—Series of hot-punched specimens showing the effect of varying silicon content on grain growth and refinement × 6

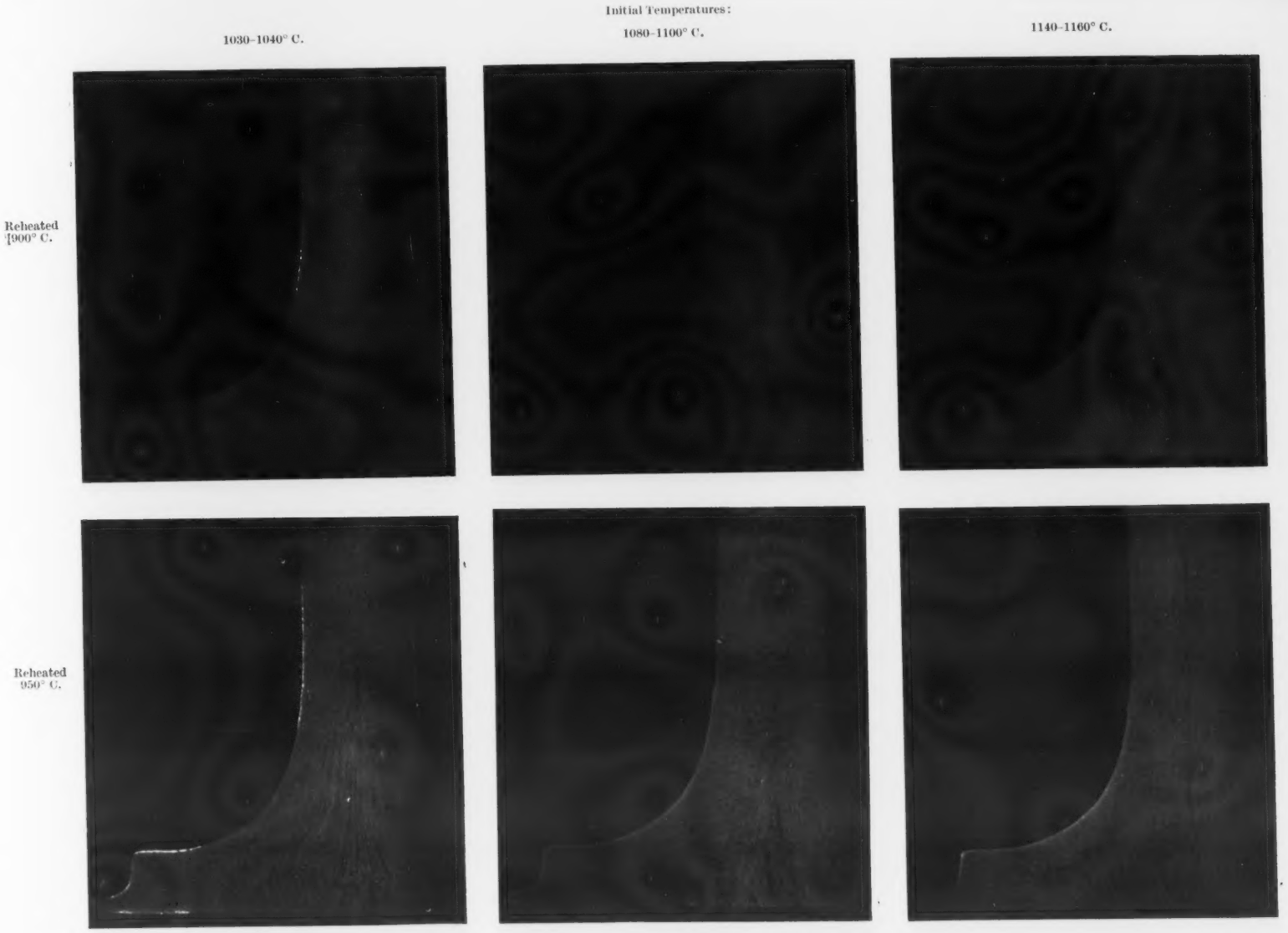

Fig. 28—Sections through valves containing 3·42 per cent. silicon forged from different temperatures × 2

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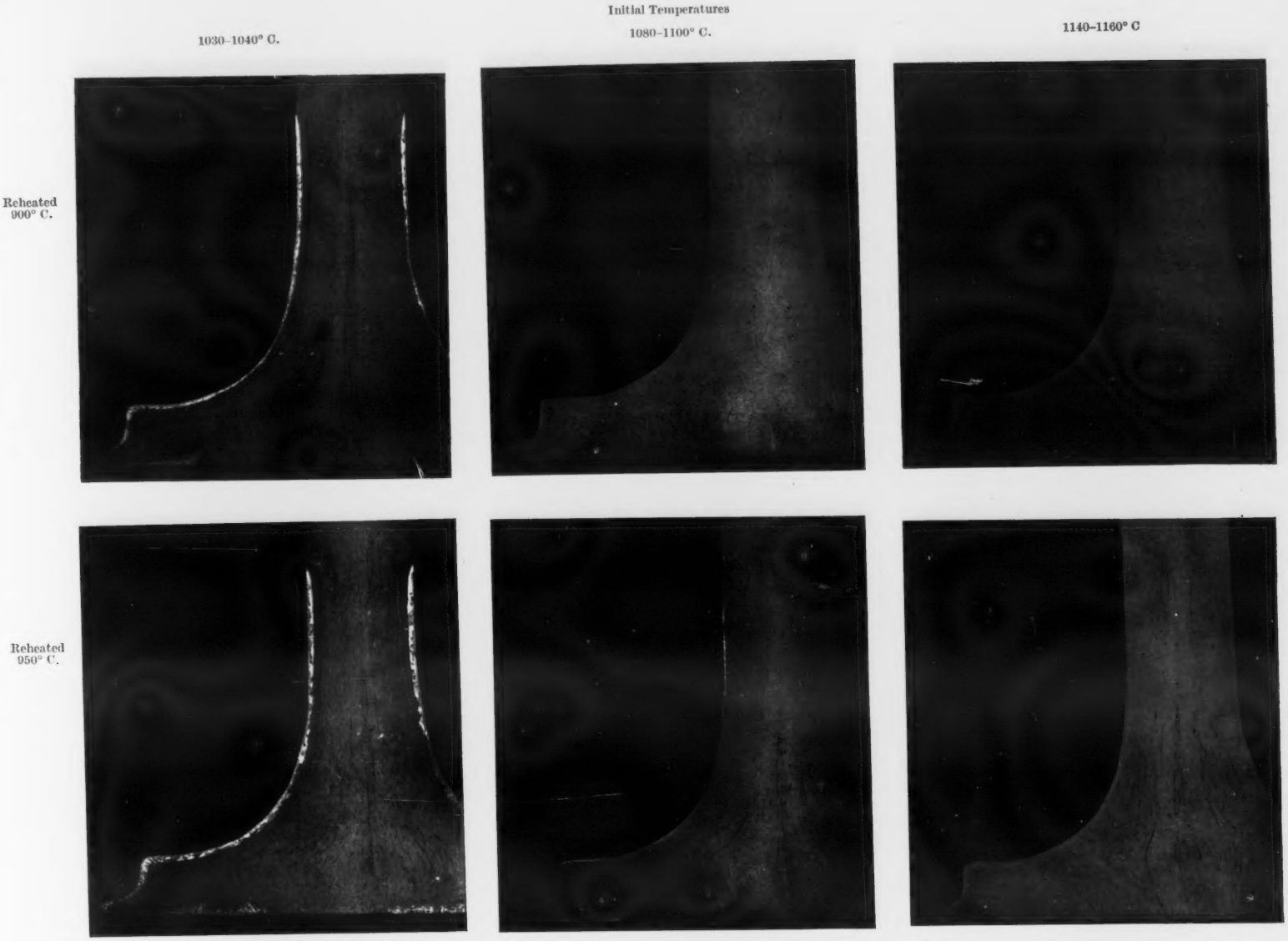


Fig. 29—Sections through valves containing 3·79 per cent. silicon forged from different temperatures × 2

Fig. 29—Sections through valves containing 3·79 per cent. silicon forged from different temperatures × 2

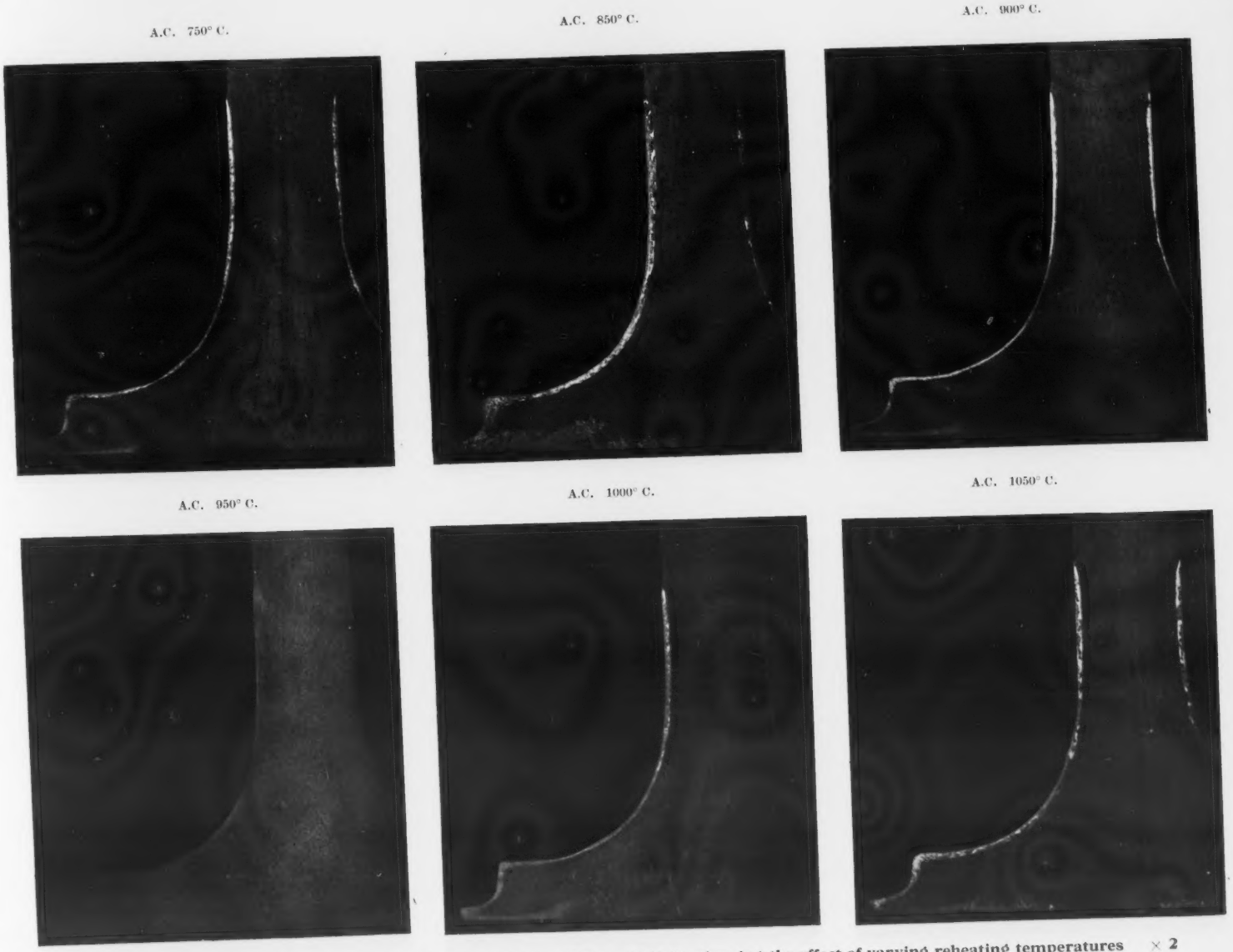


Fig. 30a—Valve sections, 3·79 per cent. silicon forged from 1030 to 1046° C., showing the effect of varying reheating temperatures × 2

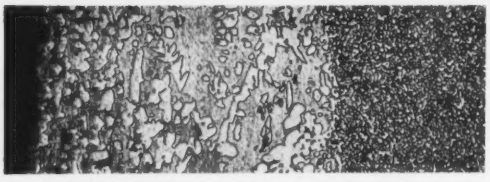
O.Q. 1000° C.

O.Q. 1050° C.

Fig. 30b—Valve sections, 3·79 per cent. silicon forged from 1030 to 1040° C. showing the effect of varying reheating temperatures × 2

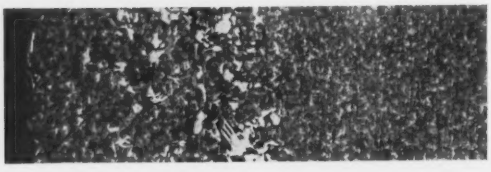
A.C. 1000° C.

O.Q. 1000° C.



A.C. 1050° C.

O.Q. 1050° C.



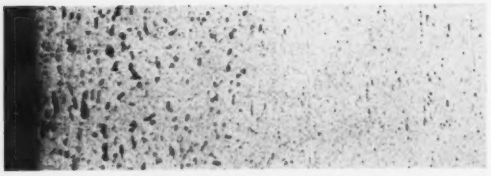
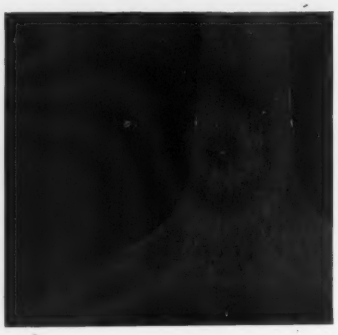


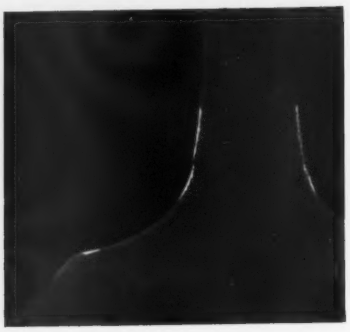
Fig. 31—Microstructures of the coarsened skins of valves (Si, 3·79 per cent.), forged from 1030 to 1040° C., showing the effect of air cooling and oil quenching from 1000 and 1050° C. × 75

Fig. 32—Sections showing the effect of initial temperature on electrically upset valves reheated to 900° C. × 2



Low ←

High →



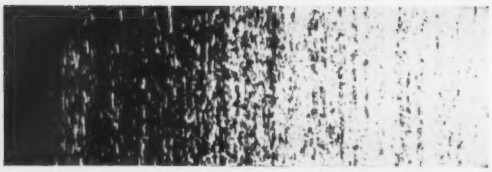


Fig. 33—Section showing preferential transformation at the surface of a valve forged from 1090° C. and water quenched × 75

Allsop and Bygate]

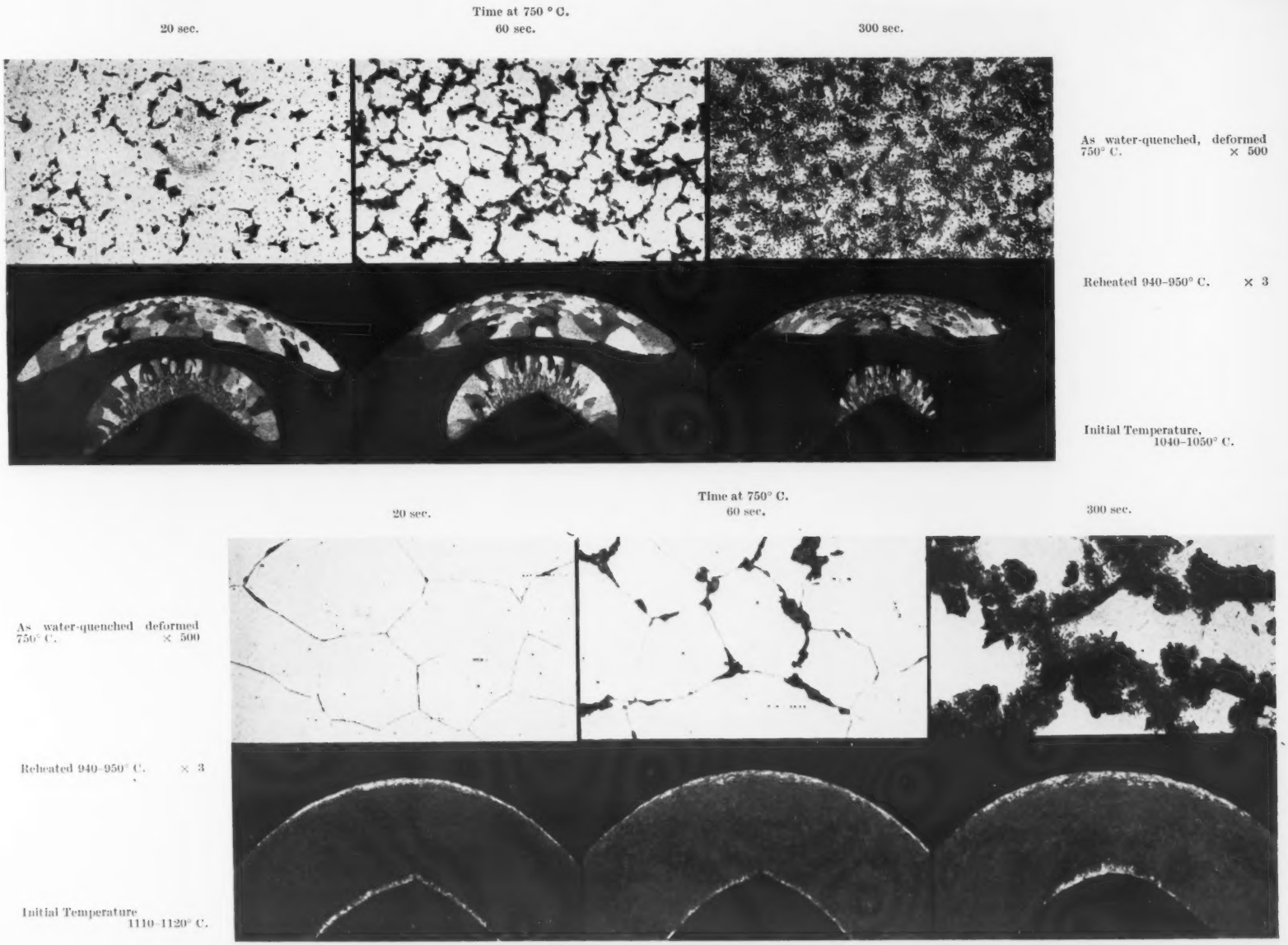


Fig. 34—The effect of initial temperature on microstructure and susceptibility to grain growth of specimens isothermally treated at 750° C., pieces reheated to 940-950° C.

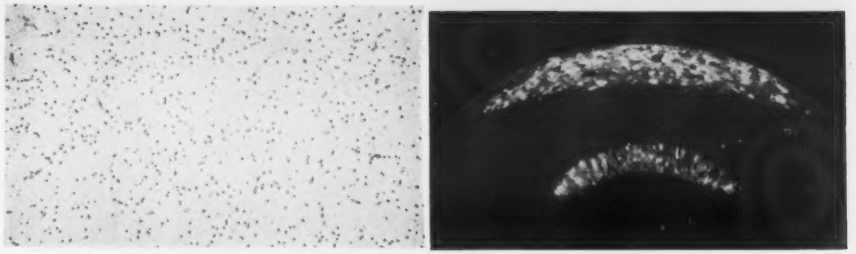


Fig. 35—Grain growth resulting from quenching to, and deforming at, (*a*) 550° C. ; (*b*) reheating to 940-950° C. The microstructure shows that no decomposition of the austenite had occurred

Fig. 37—Grain growth in a specimen quenched in oil at 200° C. and deformed when magnetic ; reheated to 940-950° C. × 3

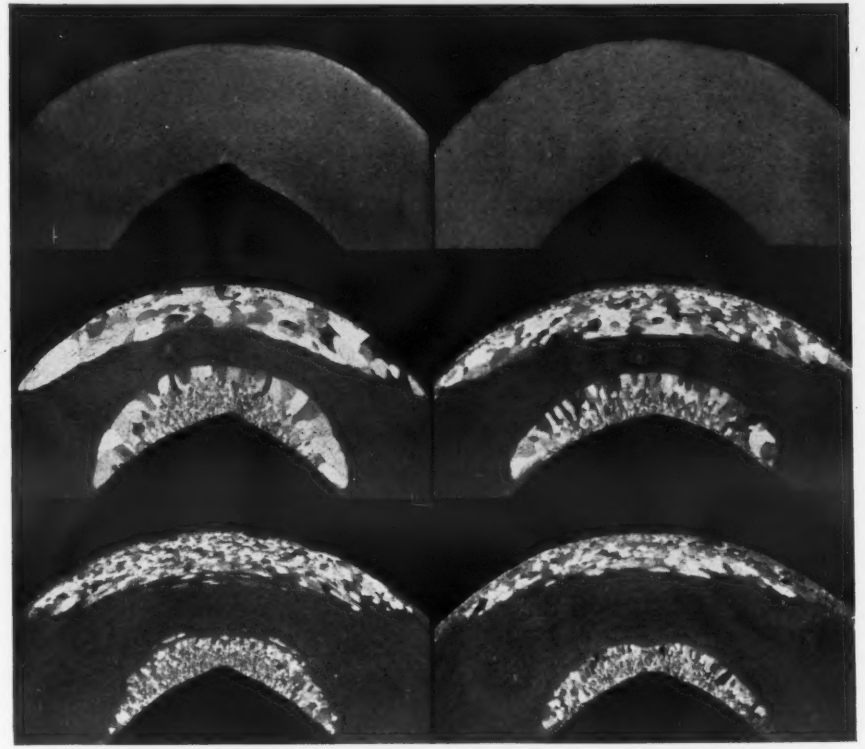


Fig. 36—The effect of quenching to, and deforming at, various temperatures on susceptibility to grain growth, reheated to 940-950° C. Initial temperature, 1040-1050° C. Pieces quenched for 20 sec., to, and deformed at, temperatures shown × 3

Fig. 38—Partial recrystallization of strained austenite in the head of a valve, water quenched after forging × 500

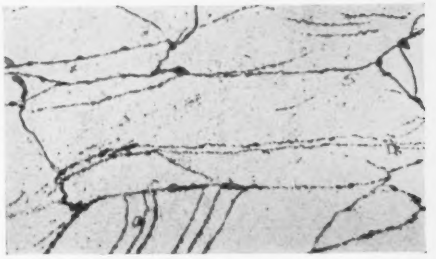


Fig. 39—Microstructure of a valve, water quenched after forging, showing incipient transformation at grain boundaries, and slip bands × 500

coarsened material. Reheating to temperatures up to 950° C. shows no evidence of any recrystallization, and the structure of pieces so reheated shows no change from that illustrated in the figures. Reheating at 975° C. shows distinct, but slight, recrystallization, as illustrated in Figs. 19 and 20. As the reheating temperature is raised, recrystallization proceeds, as shown in Figs. 21 to 26, but is not complete until the temperature reaches 1025–1050° C. The constituents of the microstructures resulting from heating to temperatures above that at which recrystallization begins depend, of course, on the subsequent rate of cooling. The pieces used were air-cooled, but as they were individually small, the greater part of the reformed austenite is retained as martensite in each structure. There is incipient decomposition of the austenite, as troostite, at the grain boundaries, which appears to provide indications of the outlines of the original coarse grains, and some of the newly formed ones, in the partially refined samples.

The evidence indicates that coarsened material is not fully refined below 1025–1050° C. It is known that in certain steels, oil-hardened nickel–chromium steel, for example, a degree of coarseness can be obtained which is not refined by heating into the austenite range, as for normal hardening. It does, in fact, require an appreciably higher temperature for its removal. It was decided, therefore, to see if the high temperature required to refine coarsened silicon–chromium steel was due to the existence of the coarse grains, or whether it was normal to the composition, in which case fine-grained material should require a similar temperature for recrystallization.

Discs cut from $1\frac{1}{8}$-in. dia. bars were oil-hardened from 1050° C., tempered at 900° C., and gave hardness values of 300 to 315 V.P.N. Individual discs were reheated to various temperatures, cooled as shown in Table I, and examined for hardness and microstructure.

These results, in respect of both re-solution and hardness, show that the fine-grained material requires practically the same temperature for complete re-solution as the coarse-grained. As in the previous case of coarsened material, partial re-solution occurs at 975° C., but is not complete until 1025–1050° C. is reached. This is confirmed by the hardness figures, which show that full hardening is not obtained below 1025–1050° C.

EFFECT OF COMPOSITION ON REFINING TEMPERATURE

All the work so far described has, as stated earlier, been carried out on a steel containing 3·74% of silicon and 8·0% of chromium, and the results show that complete refinement of coarsened material is not achieved by heating to temperatures less than 1025–1050° C., and also, that the same temperature is necessary if full hardening is to be obtained, whether the material is coarse grained or not. The silicon content of this material is practically the upper limit allowed by specification En 52, but the chromium content could be increased by a further 1·5%, and it seemed likely that in a steel containing 3·75% of silicon, and 9·5% of chromium, refinement and hardening would require a temperature in excess of the 1050° C. permitted by the specification.

Accordingly, two series of steels were obtained, one high and one low in chromium, both varying in silicon. The compositions of the steels are as follows:

C, %	Si, %	Mn, %	Cr, %
	7·7–8·0% Chromium		
0·42	2·80	0·50	7·7
0·46	3·13	0·51	7·7
0·44	3·52	0·63	7·8
0·46	3·74	0·53	8·0
	9·3–9·6% Chromium		
0·48	2·66	0·38	9·6
0·47	3·35	0·51	9·4
0·49	3·71	0·43	9·3

The alpha–gamma transformations, on heating these steels, have been investigated by means of inverse rate curves. The results obtained are given in Fig. 40, the temperatures shown being the completion of the change for the various steels. From these results, the change for the steel previously used (Si, 3·74%; Cr, 8·0%) is complete at 975° C., but the microstructural changes, illustrated in Figs. 17 to 26, show that recrystallization is not complete below 1025° C.,

Table I

HARDNESS VALUES AND MICROSTRUCTURES IN SILICON–CHROMIUM TEST-PIECES AFTER WATER-QUENCHING AND AIR-COOLING

C, %	Si, %	Mn, %	Cr, %	Ni, %
0·46	3·74	0·53	8·0	0·20

Discs oil-hardened at 1050° C., and tempered at 900° C.

Reheating Temperature, °C.	Water-Quenched	V.P.N.	Air-Cooled	V.P.N.
925	No re-solution	306–312	Fully resolved with no re-solution	305–308
950	Slight re-solution throughout	333–343	No apparent re-solution	305–308
975	Considerable re-solution throughout	450–473	Re-solution not apparent; there is slight rearrangement of carbides in certain bands	305–306
1000	Considerable re-solution, more than 975° C.	540–639	Appreciable amount of troosto-sorbite with some martensite laths	315–353
1025	Almost completely martensitic, occasional ferrite residues	759–766	Martensite, with a considerable amount of troostite in certain bands and at grain boundaries, occasional areas of ferrite	502–562
1050	Completely martensitic	683–726	Almost entirely martensitic, with some troostite at grain boundaries	532–571

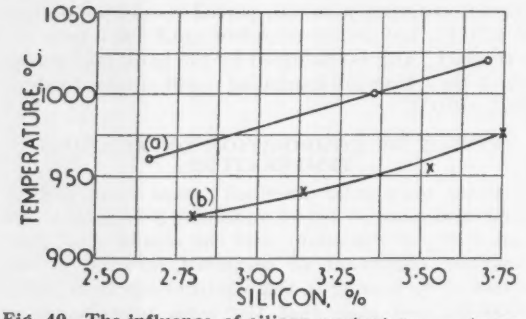


Fig. 40—The influence of silicon content on α–γ transformation temperature for steels of *(a)* high and *(b)* low chromium contents

and further, the hardness values given previously show that the material is not fully hardened at temperatures below 1025° C., even by rapid quenching. In view of this apparent discrepancy, small samples of the various steels have been hardened in oil from different temperatures. The hardness values obtained are plotted in Fig. 41, in which the alpha–gamma change (completion, by thermal curve) is marked on the hardness curve of each particular steel. The observation, made earlier, that full hardening with a content of 3·74% of silicon and 8·0% of chromium, requires a temperature of 1025–1050° C., although the alpha–gamma change is complete at 975° C., is confirmed by these results, and approximately the same temperature interval between the completion of the change and the optimum hardening temperature is shown in each steel. The earlier work also showed that grain refinement was not complete for steel containing 3·74% of silicon and 8·0% of chromium at temperatures of less than 1025–1050° C., and the refining temperature has been investigated on all four steels of the lower-chromium series (*see* p. 321).

In order to ensure that all the steels would coarsen, small pieces were hardened and tempered, deformed cold by Brinell test, reheated, air-cooled, sectioned, and etched. The heat-treatment and reheating temperatures were varied to suit individual steels, with the results given in Table II, which also includes the approximate depth of the coarsened zone.

These samples showed that all the steels would

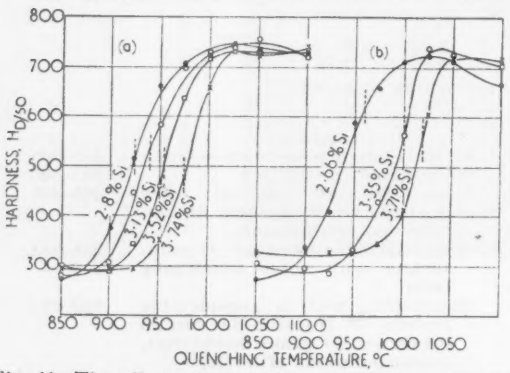


Fig. 41—The effect of quenching temperatures on the hardening of steels of varying silicon contents and *(a)* low and *(b)* high chromium contents

coarsen, but that coarsening appeared to increase, both in extent and size of grain produced, with increasing silicon content.

In order to follow the refinement of coarsened grains, a number of samples of each of the low-chromium series were prepared as follows:

(i) Hardened and tempered, using temperatures as in Table II
(ii) Reheated, with silicon contents of:
  (*a*) 2·8%, at 875° C.
  (*b*) 3·13%, at 890° C.
  (*c*) 3·52%, at 900° C.
  (*d*) 3·74%, at 925° C.
(iii) Punched at reheating temperature, as in (ii)
(iv) Air-cooled
(v) Reheated to temperatures shown in Fig. 27.

These series of pieces, including one of each steel not reheated after hot deformation, were sectioned and etched with both Hodgson's reagent and acid ferric chloride. The macro-etch for the whole series of samples, given by the Hodgson reagent, is shown in Fig. 27. Examination of the microstructures with a ferric chloride etch confirmed the respective refinement temperatures apparent in Fig. 27. It will be noted that the respective refinement temperatures for all four steels are considerably higher than the transformation temperatures given by inverse rate curves (*see* Fig. 40) and are, in fact, the same as those required to give full hardening in each steel, as shown in Fig. 41. The structures illustrated in Fig. 27 indicate that grain growth may differ with varying silicon content.

THE OCCURRENCE OF GRAIN GROWTH IN VALVE FORGINGS

Perhaps the most important observation resulting from the laboratory work, from the valve makers' standpoint, is the effect of the initial forging temperature on the susceptibility of the material to grain growth.

Facilities were made available for valves to be forged in normal production plant under controlled conditions. Valves of a standard pattern were made, using two steels of different silicon contents, from different forging temperatures. The analyses of the steels used were:

	C, %	Si, %	Cr, %
(1)	0·47	3·42	7·9
(2)	0·44	3·79	8·1

Valves were forged from 1030–1040° C., 1080–1100° C. and 1140–1160° C. Following normal procedure in this plant, the valves were air cooled after the completion of forging. Valves forged from each of the temperatures were reheated at 900° C. and 950° C., sectioned, and etched. Figures 28 and 29 show the etched sections through the heads of the valves, in the lower- and higher-silicon steels, respectively.

Table II

EFFECT OF VARYING SILICON CONTENT ON GRAIN GROWTH

Silicon Content, %	Hardening Temp., °C.	Tempering Temp., °C.	Hardness, V.P.N.	Reheating Temp., °C.	Depth of Grain Growth Behind Impression, in.
2·8	1000	850	293–298	875	0·045
3·13	1025	870	294–298	890	0·055
3·52	1025	880	303–308	900	0·070
3·74	1050	900	305–310	925	0·075

The valves shown in Figures 28 and 29 have been reheated to temperatures likely to produce grain growth if the prior conditions have been suitable. Figure 30 shows the effect of various reheating temperatures from 750° C. up to and including 1050° C., on the higher-silicon valves, forged from 1030–1040° C. No grain growth occurs as a result of reheating to 750° C. Reheating at 850° C. shows very distinct coarsening, which increases in amount to 950° C., and whilst there is some refinement at 1000° C., the coarsening is not entirely removed at temperatures below 1050° C., and then only if the valve is oil-quenched. The comparative effects of air-cooling and oil-quenching from 1000° C. and 1050° C., on the microstructure of the coarsened skin of the valve, are shown in Fig. 31.

These valves confirm the previous findings in respect of the effects of forging temperature, silicon content, and reheating temperature, on grain growth.

Valves are also made in this plant by electrical upsetting. As a further check on the effect of forging temperature, additional valves were made by the electrical upsetting process, the upsetting temperature being deliberately varied, but not actually measured, owing to practical difficulties. In the ordinary way, valves made by this method are struck once, or twice, in a friction-driven screw press. As a further variable, valves were made under each upsetting condition, namely, by two blows or one blow only. Sections through the heads of these various valves, after reheating at 900° C., show that the valves which received two blows are far more susceptible to grain growth than those struck once only, and also that the hotter valves are not as susceptible to grain growth as are those forged from lower temperatures. Figure 32 shows sections through reheated valves forged from low and high temperatures, and again, only the valve forged from the lower temperature shows appreciable grain growth. Since this method of heating creates a temperature gradient at the top of the valve stem, some portion of the valve reaches a temperature of 1030–1040° C., and therefore very localized grain growth may occur, notably towards the stem proper, irrespective of the nominal forging temperature.

It had been considered that the hardened and tempered structure, or a structure approximating very closely to it, was necessary for coarsening, but it was observed in the forging of the valves that little chilling took place in the extrusion dies and it appeared unlikely that the temperature was sufficiently reduced by the first (extrusion) dies to cause any transformation of the austenite and, therefore, the hardening which had been thought to occur. This was confirmed by the examination of extruded uses; there was no evidence of any low-temperature transformation in these samples, nor was any grain growth produced in them by reheating. Further valves were made from the same three forging temperatures as previously used, but after extruding, each valve was reheated to its appropriate initial temperature before coining. Valves made in this manner, reheated to 950° C., show grain growth in those forged from 1030–1040° C. only, precisely as in the valves made by the normal process, *i.e.*, without an intermediate reheating between the two stages of forging.

The evidence, therefore, is that the conditions of strain, which give rise to grain growth, arise in the coining dies.

Examination of the microstructures of valves, rapidly water-quenched after completion of forging, shows no evidence of the hardened and tempered structure which it has been earlier suggested occurs in forging, and this would be expected in view of the observation that the condition of strain is produced in the coining dies only. The water-quenched valves are completely martensitic, except for a skin effect about those portions chilled by the coining dies, in which some transformation has occurred. These portions show heavy distortion. Valves forged from all three forging temperatures show this same general effect, but as the forging temperature is increased, both the thickness of the transformed skin and the degree of the transformation therein, decrease. Valves given the intermediate reheating between the two stages of forging also show the same general effect, except that, for comparable temperatures, the reheated valves show a rather thinner transformed skin than those not reheated. Figure 33 shows the transformed zone at the edge of a valve forged from 1090° C. and water-quenched immediately after forging.

The transformed portion is subject to strain, chilling by the dies and, possibly, some reheating by the hotter interior of the valve. The preferential transformation of the skin may therefore be caused by its being chilled to the temperature at which transformation most readily occurs, *i.e.*, the nose of the T.T.T. curve, an accelerating effect of stress on transformation, or a tempering effect on chilled (hardened) material. There is little evidence that the last effect occurs, as, irrespective of whether the valve is reheated prior to coining or not, it is chilled under the head by the coining dies to a temperature estimated to be of the order 650–700° C., and after withdrawal from the dies, little rise in surface temperature occurs as the valve is air-cooled.

Experiments with isothermally treated pieces showed that transformation occurred most readily at about 750–775° C., and that breakdown of the austenite started in about 15 sec. Samples of the higher silicon steel (1) (*see* p. 322) were heated to 1040–1050° C. and 1110–1120° C., quenched to 750° C. for 20, 60, and 300 sec., bent in the Charpy machine, as previously described, and air-cooled. Companion pieces were water-quenched after bending. The pieces air-cooled after bending were reheated to 940–950° C., sectioned, and macro-etched, and are shown together with the microstructures on the undistorted part of the water-quenched pieces (not reheated), in Fig. 34. The difference in grain growth resulting from the variation in forging temperature is again very clearly seen.

The piece quenched from 1050° C. for 20 sec. shows that incipient transformation had taken place and, apart from the distortion, this structure is not unlike that observed in the skin of the valves. As the temperature of isothermal transformation falls below 750° C., the incubation period for the commencement

of transformation increases considerably, and at 550° C., it is appreciably longer than 30 sec. Figure 35 shows the microstructure of a piece quenched to 550° C. for 30 sec., followed by water-quenching. The same figure shows the macro-etch on a companion piece quenched to 550° C. for 30 sec., bent as described, and reheated at 940–950° C. No transformation of the austenite had occurred, but grain growth resulted from reheating. The absence of transformation products served to show that it was possible to quench a piece of the size required for the Charpy bend (8 mm. sq. × 60 mm. long) fast enough to miss the nose of the T.T.T. curve, and a series of pieces was quenched for 20 sec. from 1050° C. into baths at temperatures varying from 900° C. down to 200° C., and then bent and air-cooled. Some of these samples, reheated and etched, are shown in Fig. 36. It should be pointed out that the immersion time of 20 sec. includes the time taken by the test-piece to cool to the appropriate bath temperature. The pieces were, of necessity, rather large, and there is some doubt whether the temperature of those quenched to 400° C. and lower had, in fact, fallen to the actual bath temperature in the 20 sec. allowed, and therefore it was not possible to decide from this series whether the effect would apply to austenite transformed to martensite or not. Consequently, a similar piece was quenched to 200° C. and maintained at that temperature until it had become strongly magnetic, when it was deformed as previously. The piece was shown by microsection to be entirely martensitic and it broke in the impact machine, but coarsened on reheating to 950° C. as shown in Fig. 37. Figures 34 to 37 show that grain growth will result from suitably reheating material, deformed at temperatures of 750° C. and lower, whether the austenite is transformed or not ; but there is a notable absence of grain growth in the pieces deformed at 800° C. and over.

CONSIDERATION OF RESULTS

It has been shown that grain growth of the order observed by Hodgson can readily be produced, in silicon–chromium steel which conforms to B.S. En 52, by cold work, followed by reheating to a sub-critical temperature. By cold work is meant actual cold deformation, or deformation of the ferritic condition at an elevated temperature, and it appears that the actual temperature of deformation is not important, provided it is sub-critical. In this particular type of steel, the degree of coarsening seems abnormally great, but otherwise, conditions giving rise to the coarsening are not new. In respect of the effect of reheating temperature, etc., the coarsening conforms to the accepted principles of grain growth, except that the coarsening appears to be structure-sensitive, since it is only from the hardened and tempered structure that excessive coarsening will develop. Even with material in the hardened and tempered condition, it is apparent that the coarsening is markedly influenced by the hardening temperature. Most pronounced grain growth results from the use of a hardening temperature which will just give a ferrite-free structure, and temperatures in excess of this give rise to progressively less coarsening.

Whilst the occurrence of grain growth, as a result of cold work (defined earlier), can be reliably reproduced in suitably hardened and tempered material, valves are not made from hardened and tempered material, and it appeared unlikely, from observations made during actual valve forging, that that condition did, in fact, occur in normal forging practice. The structures in the forged valves are confused by heavy distortion in those portions which coarsen on reheating, and although, when rapidly water-quenched from forging, the valves show preferential transformation in the chilled and strained parts, there is no evidence to indicate that preferential transformation is an essential factor in grain growth. The experimental work following the observation of actual forging shows that, providing the material has been heated to a suitable initial temperature, it will coarsen on reheating, although, at the time of straining, it may be either wholly untransformed austenite or austenite transformed to give widely different structures. There is evidence to indicate that the temperature at the time of straining is not critical if it does not exceed 750° C., but, apparently, coarsening on reheating does not take place on material strained at temperatures of approximately 800° C. and above. These observations regarding the coarsening of material strained at temperatures up to about 750° C. apply only to material heated to an initial temperature of about 1050° C. If the initial temperature is higher, *i.e.*, 1100° C. or over, similar straining conditions give rise to no grain growth at all, or only to a very slight extent. This effect of initial temperatures on ultimate coarsening is consistently shown throughout the whole work, *i.e.*, on the hardened and tempered bars, on the actual valves, and on the laboratory samples treated to simulate valve-making conditions.

The absence of grain growth from samples strained at temperatures of approximately 800° C. and over, previously noted, is believed to be due to self-annealing of the strained austenite by recrystallization, and evidence that this may occur can be observed in some of the valve forgings, as shown in Fig. 38 which illustrates the structure in the head of a valve water-quenched after forging.

Although it is not considered that the preferential transformation noted in certain parts of the valves is a necessary condition in their coarsening, it is thought to be of general interest that there is evidence that transformation is facilitated by strain. Although the complete T.T.T. curve was not explored, evidence was obtained to show that, after austenitizing at 1050° C., the nose of the curve occurred at about 750–775° C., at which temperature the incubation period for the commencement of breakdown of the austenite was of the order of 15 sec. In the case of the valves water-quenched immediately from forging, the time at 750° C., or thereabouts, was only about 3 sec., but selective transformation had occurred and, further, it appears that transformation of strained austenite may commence on slip planes in addition to the grain boundaries, as Fig. 39 shows. It also appears that the speed of isothermal transformation is influenced by the austenitizing temperature. In the samples isothermally treated at 750° C., there is

more transformation, for comparable times (*see* Fig. 34), in the pieces which have been heated to 1050° C. than in those heated to 1120° C. This indicates that, as a consequence of higher austenitizing temperature, the T.T.T. curve is displaced along the time axis in the direction of increasing time, which effect has been previously observed on different steels by other workers. It is not suggested, however, that the effect of the austenitizing temperature on the T.T.T. curve provides an adequate explanation for the difference in grain growth resulting from different initial temperatures, and no precise explanation is offered for that effect.

If the forging conditions (and presumably the effect would apply to other hot-working processes, *e.g.*, rolling of small sections) are such as to give rise to strain under the conditions outlined previously, grain growth will result from reheating at those temperatures up to which re-solution of the carbide commences, and refinement of the coarsened grains begins. As the reheating temperature is further raised, progressive refinement occurs, but the outlines of the coarsened grains persist, and are not entirely removed until the temperature reached is sufficient to remove all free ferrite. This temperature, which increases with increasing silicon content, is some 50° C. higher than the transformation shown by an inverse rate curve, and consequently, although a steel with 3·74% of silicon and 8·0% of chromium shows the phase change complete at 975° C., complete refinement of coarsened grains requires a temperature of not less than 1025° C. Steels of lower silicon content show the same effect, except that the indicated phase changes and refining temperatures are progressively lower as the silicon content is less; but, apart from the effect of decreasing silicon on the temperature needed to obtain refinement, it appears that the tendency to coarsen is reduced with decreasing silicon content. The hardening temperature range, 1000–1050° C., specified for B.S. En 52, is not sufficiently high for steels towards the top end of the specification, in respect of silicon and chromium, although it may be suitable for steels of lower silicon and chromium. If valves are machine forged from temperatures of the order of 1030–1050° C., it would seem inevitable that, unless they are effectively hardened, coarsening will occur in the radius under the head. If such valves are tempered only, they will coarsen if the tempering temperature is 850° C., but if they are tempered at 750° C., grain growth is likely to be very slight and perhaps negligible. It would appear good practice that valves should be completely heat-treated, *i.e.*, adequately hardened and tempered; inefficient hardening by the use of too low a temperature will result in excessive grain growth. The evidence indicates that, when coarsened, this material is brittle, even at temperatures approximating to those at which such valves may operate, but no valves have been observed in which the effect penetrated deeper than about $\frac{1}{16}$ in. Even forging from temperatures as low as 930° C. failed to produce a valve coarsened completely through. Even so, the brittleness of the coarsened skin might give rise to a crack which, once started, would probably penetrate through the finer material of the interior quite quickly, and, therefore, coarsening of the skin only might lead to premature breakage of the valve.

If the forging temperature is of the order of 1100–1150° C., the chances that the valves will coarsen are very much reduced.

CONCLUSIONS

(1) An unusual degree of grain growth may occur in B.S. En 52-type valve steel on reheating critically strained material. The coarsening increases with increasing reheating temperature up to that at which re-formation of austenite commences. If the material is strained in the ferritic state, coarsening is very structure-sensitive, and only the hardened and tempered condition gives rise to severe grain growth.

(2) Severe grain growth may also result from reheating material strained during forging if, at the time of straining, the temperature of the material has fallen to something below approximately 750° C. If the temperature at straining is below 750° C., the material may be austenitic, or partially or wholly transformed, without significant effect on coarsening. The grain growth found in valves is due to the straining of under-cooled austenite, or its decomposition products, during forging.

(3) Grain growth due to either of the above causes is strongly influenced by the austenitizing temperature, *i.e.*, hardening temperature, or forging temperature. In otherwise critically strained and reheated material, little or no grain growth will occur if the prior austenitizing temperature has exceeded 1100° C.

(4) The occurrence of critical straining, in certain portions of valves made by machine forging, *e.g.*, extrusion and coining and electrical upsetting, appears inherent to that process. If forged from a suitable temperature, such valves will coarsen on reheating, but, if the reheating temperature does not exceed 750° C., the coarsening is not appreciable, and may be negligible. If the valves are hardened and tempered the hardening temperature must be adequate to effect complete refinement. If the hardening temperature is low, excessive grain growth will persist.

(5) Coarsened material is notch brittle at elevated temperatures.

(6) Refinement of coarsened material requires a temperature 50 to 75° C. higher than the phase change indicated by an inverse-rate curve. The necessary temperature increases with increasing silicon and chromium contents, and may not be adequately met by the hardening temperature range specified for B.S. En 52.

(7) Under similar conditions of strain, etc., the degree of coarsening increases with increasing silicon content.

Acknowledgments

The authors' thanks are due to the Directors of Messrs. Brown, Bayley's Steel Works, Ltd., for permission to publish this paper, and to their colleague, Mr. K. L. Green, who has carried out all the photographic work. They also wish to express their appreciation of the willing co-operation of Messrs. D. Doncaster and Sons, Ltd., by whose kindness the experimental valve forging was made possible.

HISTORICAL NOTE No. 11

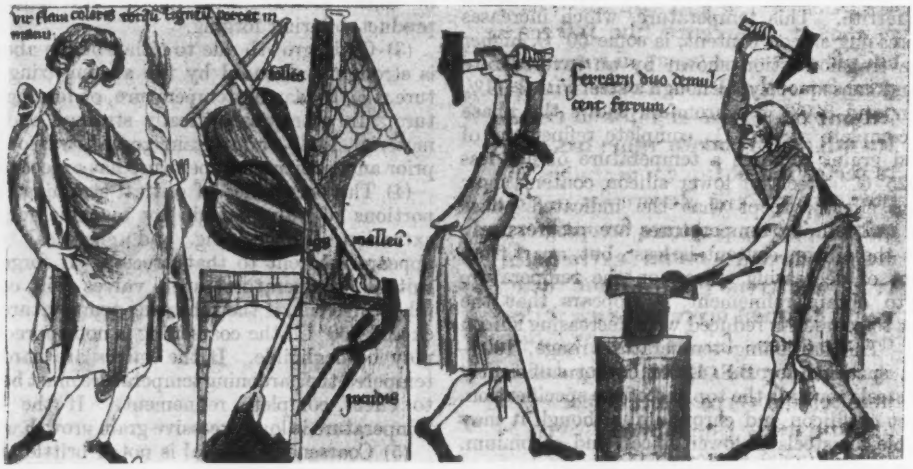
Medieval Ironworks at Monmouth and Osbaston in Monmouthshire

By Dr. H. R. Schubert

IN the early twelfth century, Baderon, the Norman Lord of Monmouth, gave to Prior Robert and the monks of the Benedictine Priory at Monmouth, founded in about 1075, three forges situated at Monmouth, on the banks of the River Wye, in exchange for Hadnock near Monmouth. Baderon also gave permission for his own men to rent these forges from the monks if they wished to, with the exception of those who already had a forge from Baderon (*forgiam meam*).[1] Altogether there were four different forges, three given to the monks, and one worked by the Norman lord's own men. The iron produced was partly consumed on the various estates belonging to the owners, and, in addition, some part of it was bought by merchants who resold it at a profit (*si quis emerit ferrum de illis forgiis ut iterum revendat causa lucrandi*) on the iron market. This is of particular interest, as it signifies an iron trade at a very early date.

The site of the three forges worked by the monks is distinctly defined as being situated in the town of Monmouth on the banks of the River Wye (*in burgo meo de Monemut supra ripam Wye*). The refuse of these forges was turned up by workmen when digging the foundations for the Science Wing of the present Grammar School at Monmouth.[2]

There is nothing in the twelfth-century charter to indicate the site of the forge Baderon reserved for his own use. In the subsequent thirteenth century, during the struggles between King Henry III and the English barons, strongholds such as Monmouth Castle became of great importance. As Baderon's descendant, John of Monmouth, had no male issue, he was induced to resign Monmouth in favour of Prince Edward, afterwards King Edward I, in 1257. Consequently, John's former possessions were administered by the King's bailiffs. Accounts of the first nine months after the resignation, beginning with July 1257, are preserved.[3] These accounts refer to revenues from a forge (*de redditibus forgiae*) at Osbaston (*villa Osberti*) which is situated on the left bank of the River Monnow, north-west of Monmouth.



It may be presumed that this forge of 1257 was the same forge which John's ancestor Baderon had reserved for his own use, when he gave his three other forges to the Priory of Monmouth, more than a century earlier.[4]

Ironworking at this early time is illustrated by a picture contained in a late-thirteenth-century manuscript.[5] It shows two ironworkers forging the iron (*ferrarii duo demulcent ferrum*) on an anvil, the hearth with a fire (*ignis*), hammer (*malleum*) and tongs (*incudis*), the bellows (*folles*), and a man in a yellow garment holding a wooden torch in his hand (*vir flavi coloris torquum ligneum portat in manu*).

Manuscript received 31st December, 1948.

[1] W. Dugdale, "Monasticon Anglicanum," vol. IV, p. 596, London, 1846; the charter is not dated, but Prior Robert occurs in the time of King Henry I, who reigned from 1100 to 1135 A.D., *loc. cit.*, p. 595, *see also* J. A. Bradney, "A History of Monmouthshire," vol. I, pp. 10–11, London, 1907.

[2] J. H. Matthews, "Old Monmouth," Archaeologia Cambrensis, sixth series, vol. IX, pp. 303–304, London, 1909.

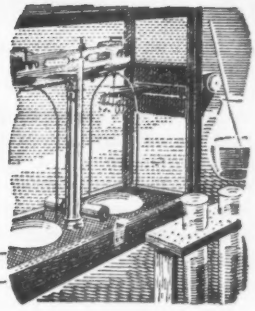
[3] Public Record Office, Duchy of Lancaster, Ministers' Accounts, Bundle 1094, No. 11.

[4] This is the earliest evidence of the forge at Osbaston which, acco ding to J. H. Matthews, *loc. cit.*, p. 304, "dates from the reign of Elisabeth."

[5] British Museum, Sloane MS. 3983, fol. 5.

B. I. S. R. A.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION



The Layout of Integrated Iron and Steel Works

A SURVEY OF SOME CIVIL ENGINEERING ASPECTS

By H. H. Mardon, B.Sc.(Eng.), M.I.C.E., M.I.Mech.E., M.I.Struct.E., M.Am.S.C.E., and J. S. Terrington, B.Sc.(Eng.), A.M.I.C.E., A.M.I.Struct.E.

SYNOPSIS

The nature and extent of the problem of the layout of an integrated iron and steel works is considered and factors are discussed concerning the selection of a site, the layout of an integrated works as a whole, and some of the criteria which determine the detailed arrangement of each of the three departments of ironmaking, steelmaking, and rolling mills. Features existing in works in Great Britain are tabulated ; a theoretical analysis of a fundamental theory of the layout of integrated iron and steel works is developed ; and a comparative study of the traffic routes of the main process materials in the principal integrated works in Great Britain is made possible by flow diagrams reproduced in colour. Owing to the complexity of the details, it is not possible in many instances to lay down precise rules to suit all conditions, but some general conclusions have been drawn. Numerous aspects require detailed quantitative analysis and the most important of these is considered to be a traffic survey of representative wroks.

Introduction

THE original terms of reference of this investigation, namely, "the formulation of general principles governing the layout of integrated iron and steel works," do not give any indication of the issues involved, and it has therefore been necessary to arrive at a more precise definition of the problem. In the section on "General Principles Governing the Layout of an Integrated Works," it is shown that the criterion by which a layout can be judged is the extent to which it permits efficient handling of materials between the unit processes and the efficient working of the processes themselves.

The main principles of works layout are largely based on practical considerations so that as wide a knowledge as possible of existing practice is essential. The authors have accordingly made a survey of numerous plants in Great Britain, including sixteen of the most important integrated works, covering all the principal areas as indicated on the map in Fig. 1.

This survey, the results of which are recorded in this paper, has been carried out mainly to throw into relief the numerous problems involved in the layout of works, and each problem may be sufficiently important to form the subject of a separate investigation. It will be appreciated that, in view of the wide scope of the survey, it has been impracticable, at this stage, to make a quantitative analysis of all the large number of items of plant, storage areas, sidings, and other accommodation, together with traffic analyses of the various parts of the works, for comparison in relation to the output of the plants. Such quantitative analyses, which may be considered desirable as a result of this survey, will require to form subjects of further investigations. For the reason referred to above, it has been impossible also in this survey to cover all aspects such as mechanical handling, the generation and distribution of power, the layout of service mains, and a number of minor items enumerated later.

It is perhaps worth noting that whereas a wealth of information has been published on the principles and practice of production in the various unit processes, little, with the exception of those works [1–8] referred to at the end of this paper, exists on planning or layout with the object of attaining maximum efficiency

Paper PE/29/47 of the Plant Engineering Division of the British Iron and Steel Research Association, received 10th November, 1948.

Mr. Mardon and Mr. Terrington are on the staff of the British Iron and Steel Research Association.

in the linking of one unit process with the other. This aspect is obviously of particular importance in iron and steel works.

Concerning this paper, the authors wish to mention that, as various factors governing the selection of a site inevitably affect the layout, it is considered relevant to include notes on them here ; that observations on plants refer to the time of the visit and will not necessarily apply after improvements, now contemplated or commenced, are complete ; that factors and desirable conditions described in this paper will have to be carefully balanced and adjusted to arrive at the best solution for any given site or set of conditions ; and that the theoretical analysis for a fundamental theory of the layout of iron and steel works developed here is believed to be the first of its kind.

Owing to the complexity of the details to be arranged, it is not possible in many instances to lay down hard and fast rules or firm recommendations to suit all conditions. In the light of the survey carried out, however, the authors have made observations on specific arrangements of plant and methods of handling which, it is hoped, may help to ventilate or focus attention on some of the problems. In the course of the observations, too, certain arrangements have been put forward for consideration but these cannot necessarily be the best to suit all conditions.

Finally, concerning the choice of a site, it is appreciated that schemes will always have to be modified to suit site conditions and capital available. It is hoped, however, that the present investigation will have demonstrated the necessity of avoiding the acquisition of sites having such limitations as are recorded in this paper.

GENERAL PRINCIPLES GOVERNING THE SELECTION OF A SITE

Essential Requirements

The selection of the area in which the site is to be located will depend, apart from broad considerations of national policy such as those of economics and strategy, upon its access being most favourable to raw and other materials and to present and future markets. In addition to the foregoing, vital necessities are the availability of adequate labour, power, and water supplies.

Considered very broadly, the quantity of incoming materials is approximately twice that of the outgoing materials. On the other hand, the average transit rate of the outgoing products, which include those of high value, is somewhat higher than the transit rate of the incoming lower-value products. The net result is that the total cost of carriage for the incoming materials is usually more than for the outgoing products. It therefore follows that convenience of access to raw materials is of more importance than convenience of access to markets, and the relatively high-value product, rather than raw materials of lower unit value, should traverse the longer distance in order to keep the ratio of transport cost to cost of material, as low as possible. This does not, of course, minimize the cost of transport of finished products, since this factor has already caused the working of one site to become uneconomic. In regard to raw materials, numerous plants owe their continued existence to the fact that their location has happened to remain accessible to alternative sources of supply even after local deposits have been worked out or after other reasons for their existence have ceased to apply. Concerning the sale of finished products, it is noticeable that industries have, in the past, been created by the presence of the works, as in the case of areas in the south-west of Scotland, in the north-east of England, and in the Midlands.

Since the development of road transport, it is essential that all works should be completely accessible by road as well as by rail. It is, of course, not implied that road transport, which is used for a proportion of the finished products from works *L* and works *O*, will necessarily supersede rail transport, but for some types of product, such as sheet and tinplate, it has been found cheaper to dispatch some consignments of these direct to their destination by road in order to shorten the transit time and to avoid double handling.

The heavier tonnages are usually more economically handled by rail, but for the lighter loads it may now be expedient in certain circumstances to use road transport. New works should therefore be easily accessible by road. Overseas markets, of course, favour sites on the seaboard.

Topography

In the selection of a new site, natural or artificial obstructions should be avoided since these can seriously affect the layout of the works (as illustrated by examples from existing works in Fig. 2 and as summarized in Table I) and can, in fact, directly increase production costs for the whole life of the plant.

Apart from actual obstructions, the other important factor is that of ground levels, and on this mattter it is considered that the maximum degree of freedom for planning is afforded by a plane level site since the effect of gravity is not ' weighted ' for or against any of the unit processes. For example, one works on the Continent has derived the maximum advantage from its location on sloping ground ; in almost all other existing works, however, upgrades for traffic usually cancel the value of any assistance received from downgrades elsewhere on the site.

On this matter of ground levels, two features are desirable to incorporate ; one, the use of gravity sidings (with, if necessary, auxiliary means of raising wagons to the highest level) at local points in the site ; and two, the selection of an area for the site which is slightly above the level of the surrounding country (somewhat in the nature of a low plateau[1]), where access is solely by rail, in order to ensure that the dispatch of the finished and waste products is not delayed by their having to be hauled out of the site against gravity.

Strata

The sub-strata of any site selected should have a stratum of firm stone, gravel, or clay, at a reasonable depth such as will enable the usual type of mass concrete foundations to be laid. If a firm stratum is not present, raft foundations or piling at often considerable extra cost will have to be adopted.

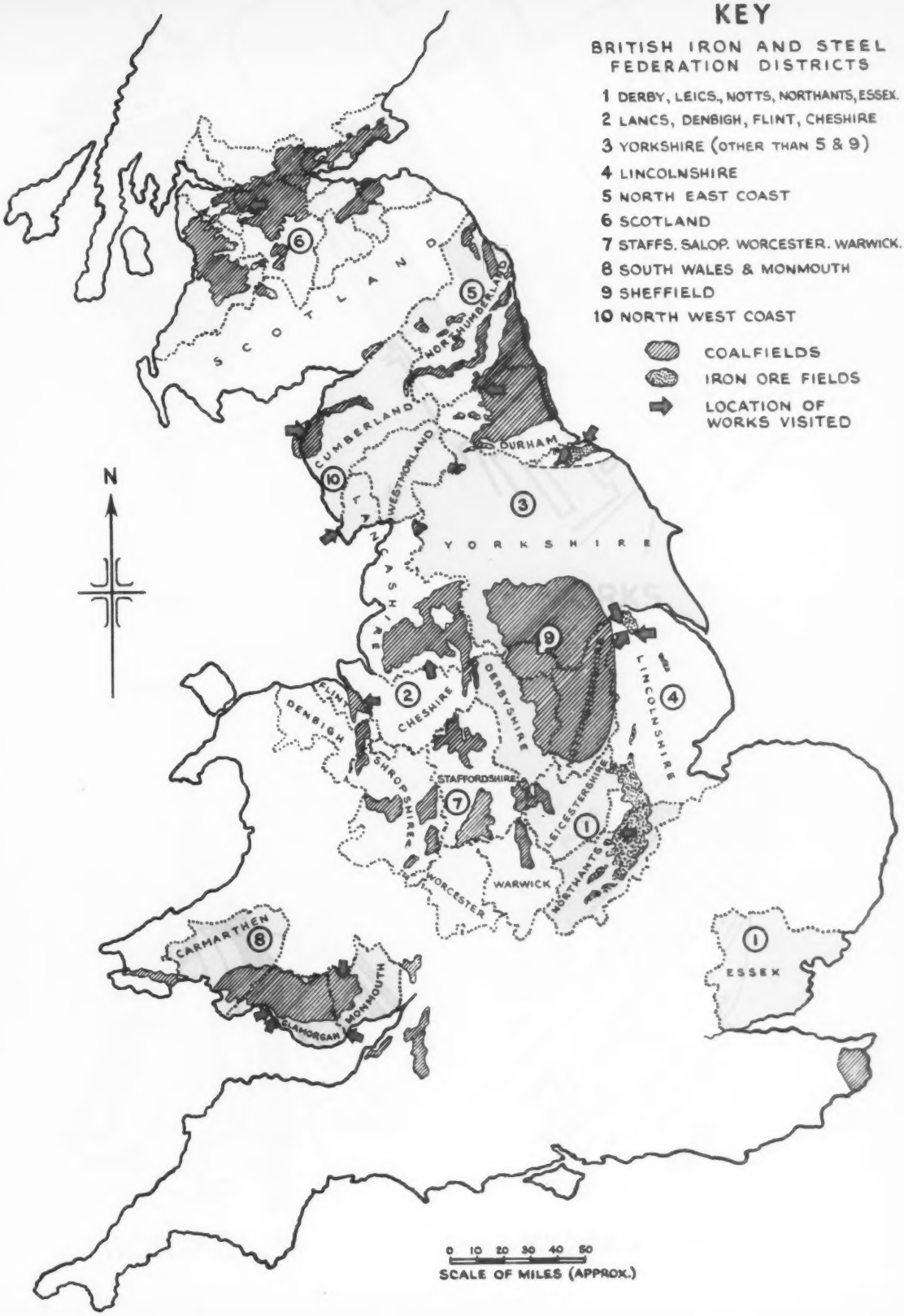
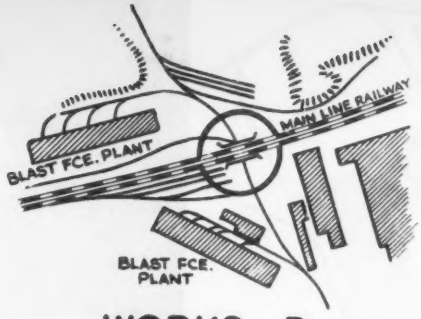
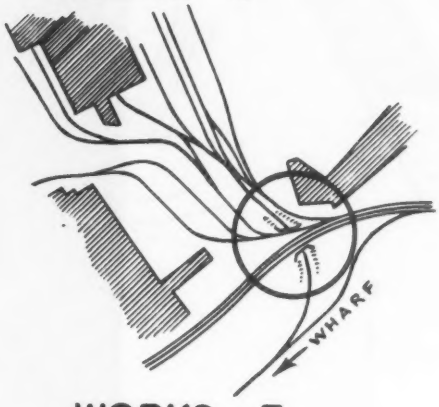


Fig. 1—Map of Great Britain showing location of works visited in relation to B.I.S.F. districts



WORKS D



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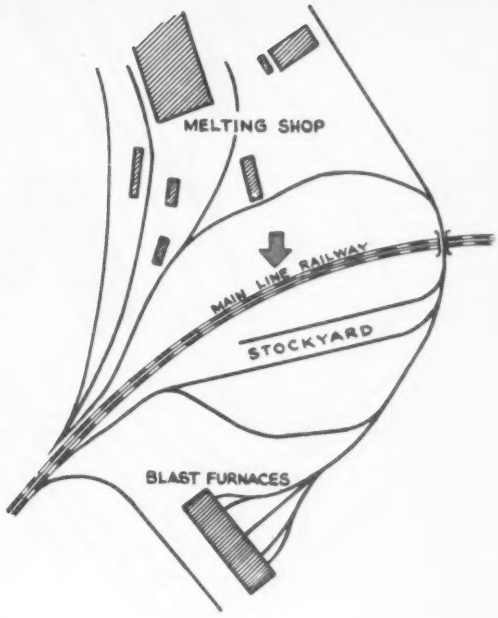

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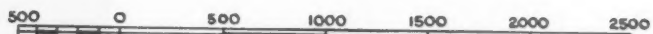

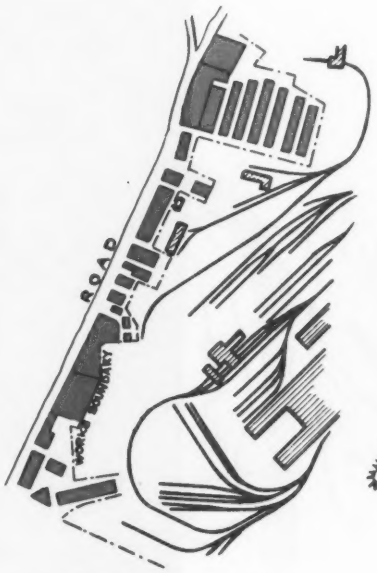

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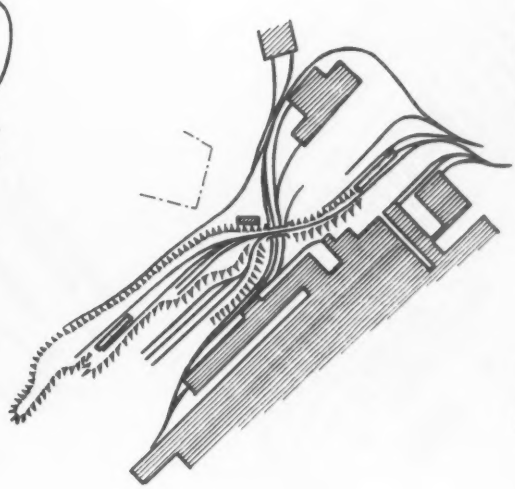

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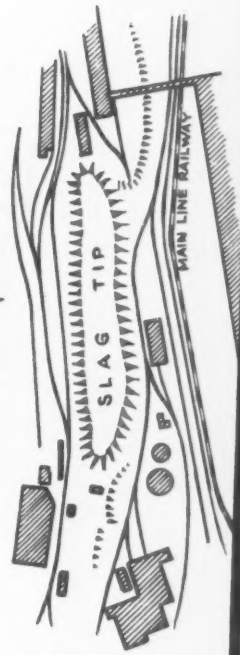

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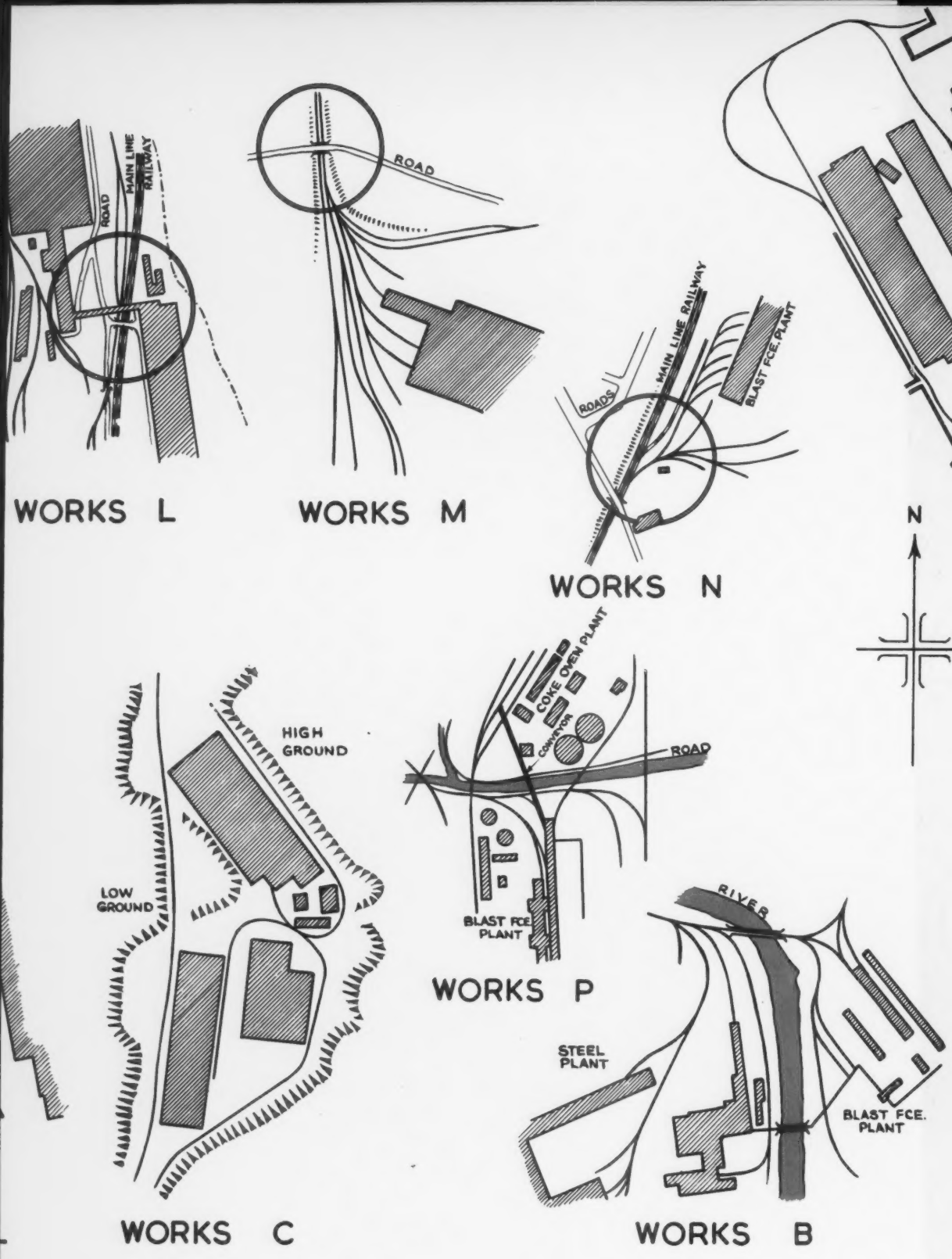
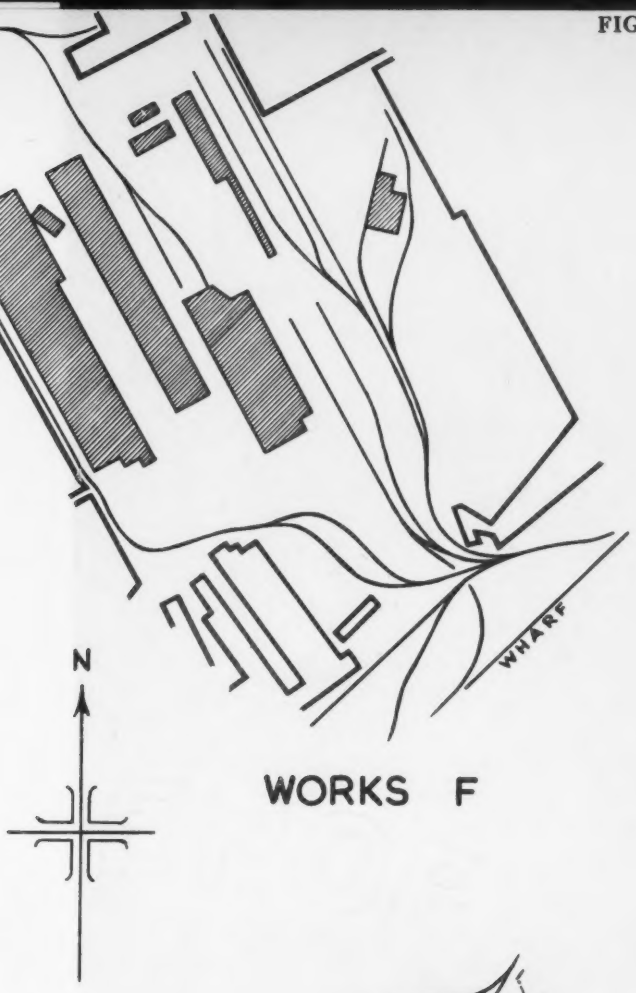


FIG. 2—TOPOGRAPHICAL FEATURES
(SEE TABLE 1)

FIG. 2



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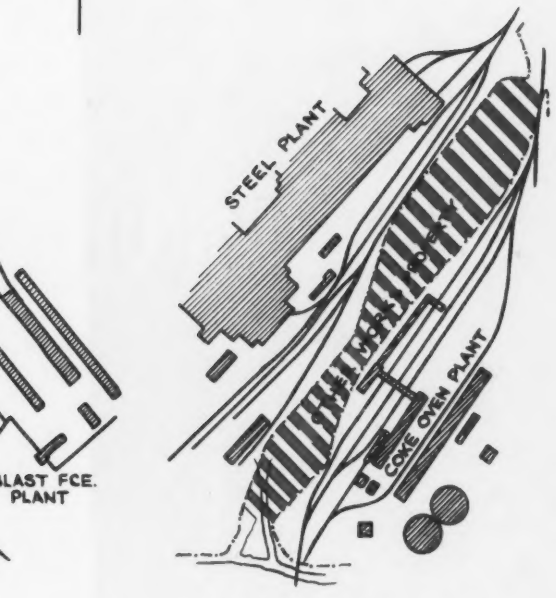

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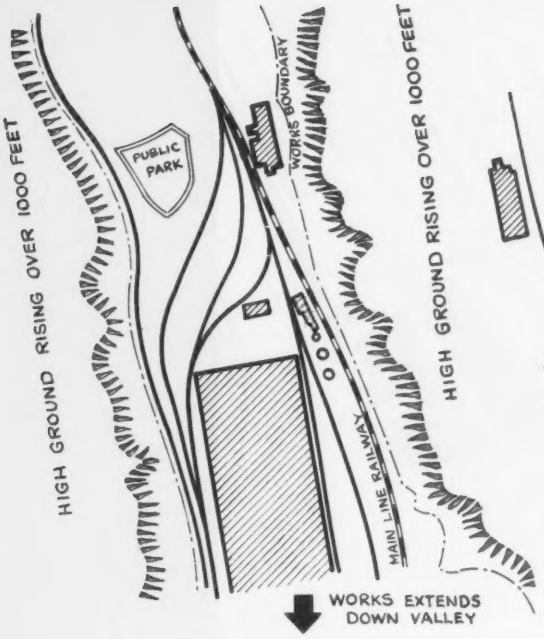

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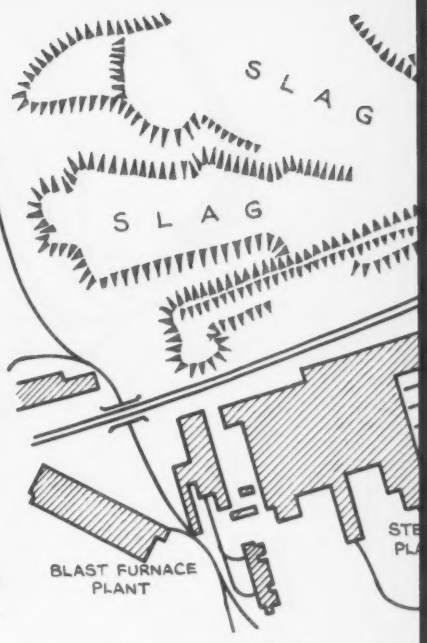

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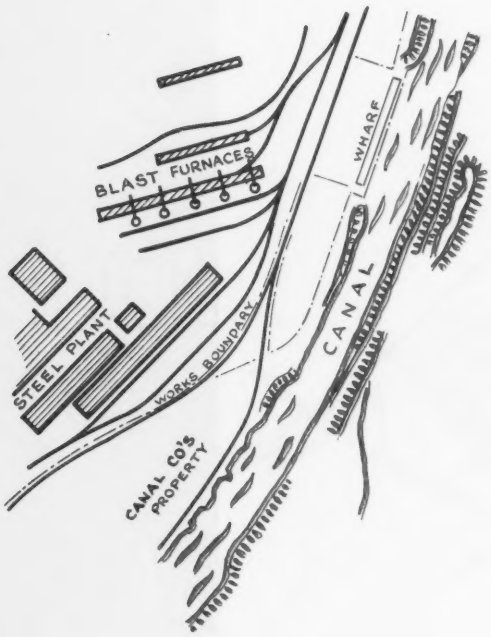

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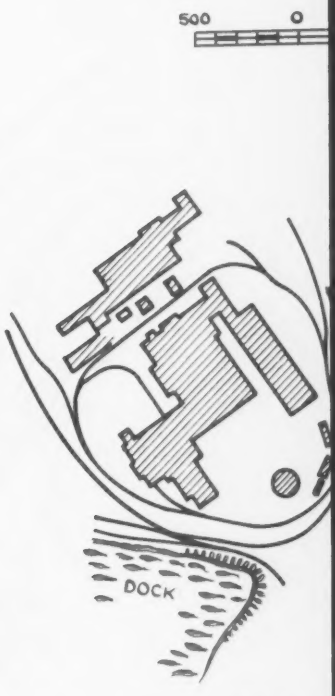

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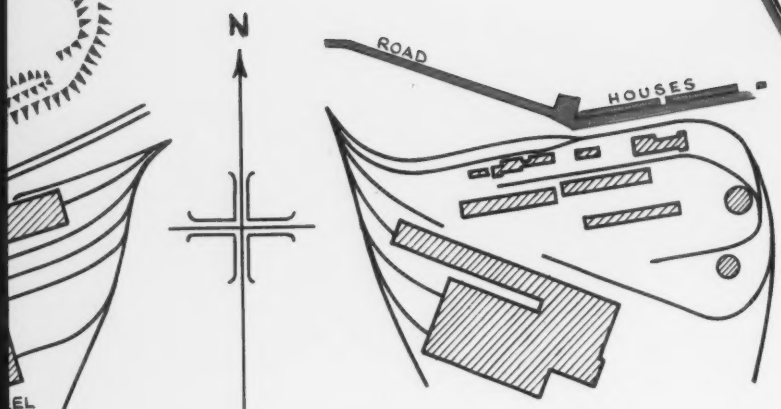
FIG. 3—

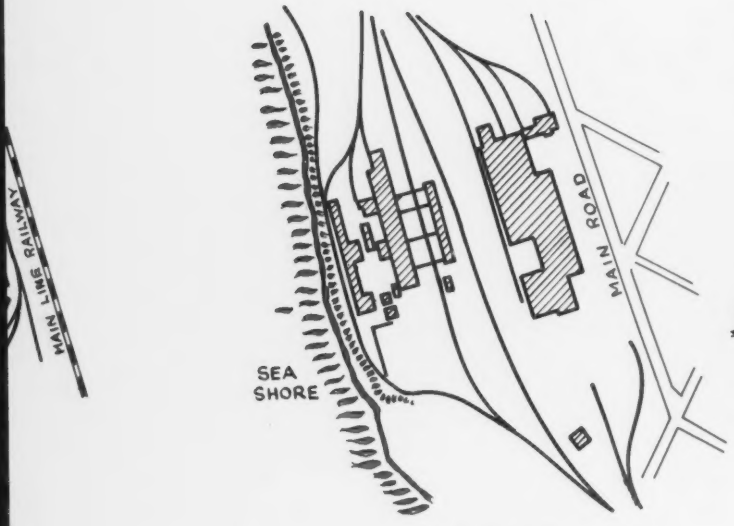


WORKS M

WORK

500 1000 1500 2000 2500

SCALE OF FEET



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WORKS A

WORKS

RESTRICTIONS TO EXTENSION
(SEE TABLE 3)

FIG. 3

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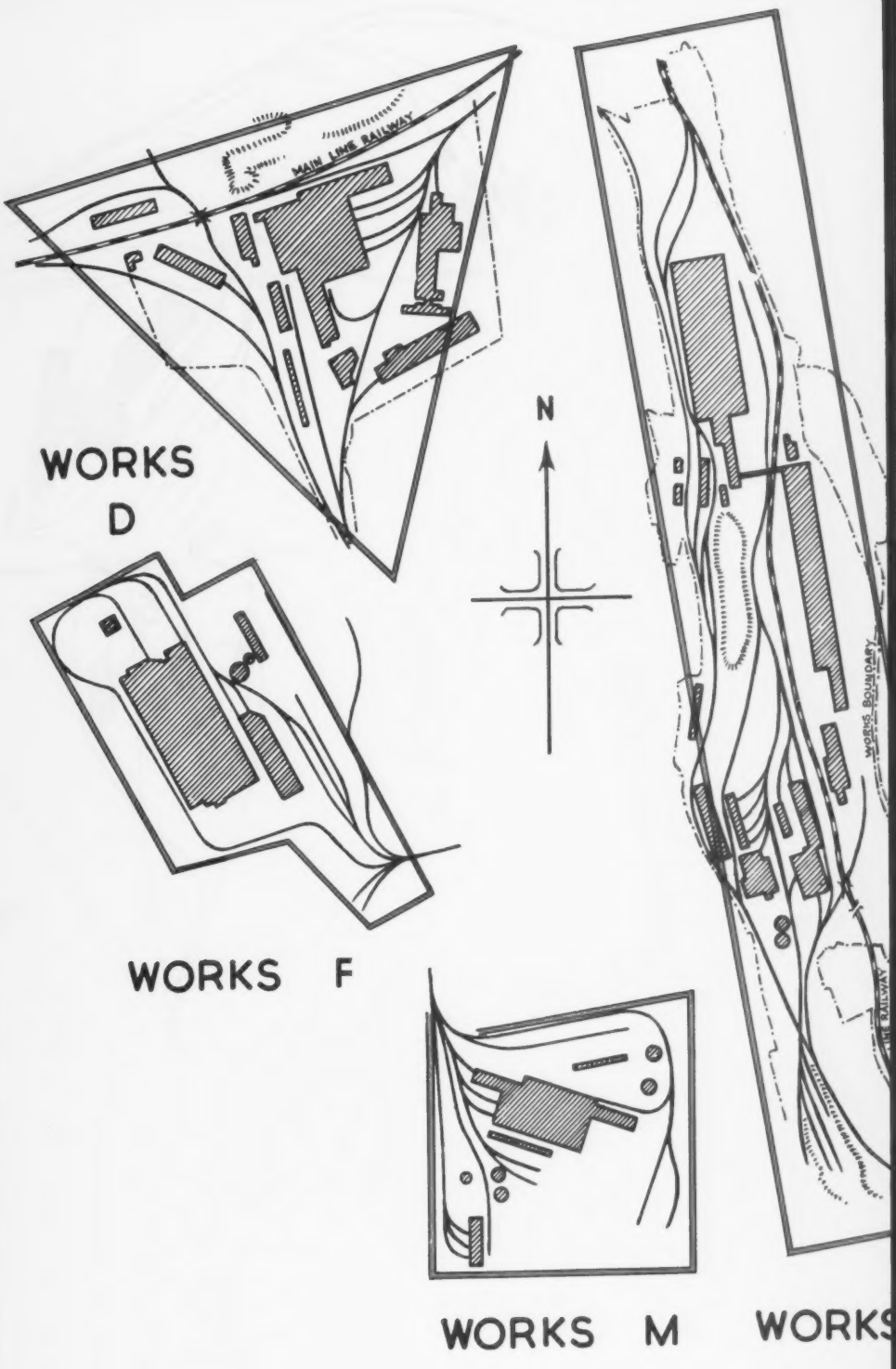
MAIN LINE RAILWAY
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N
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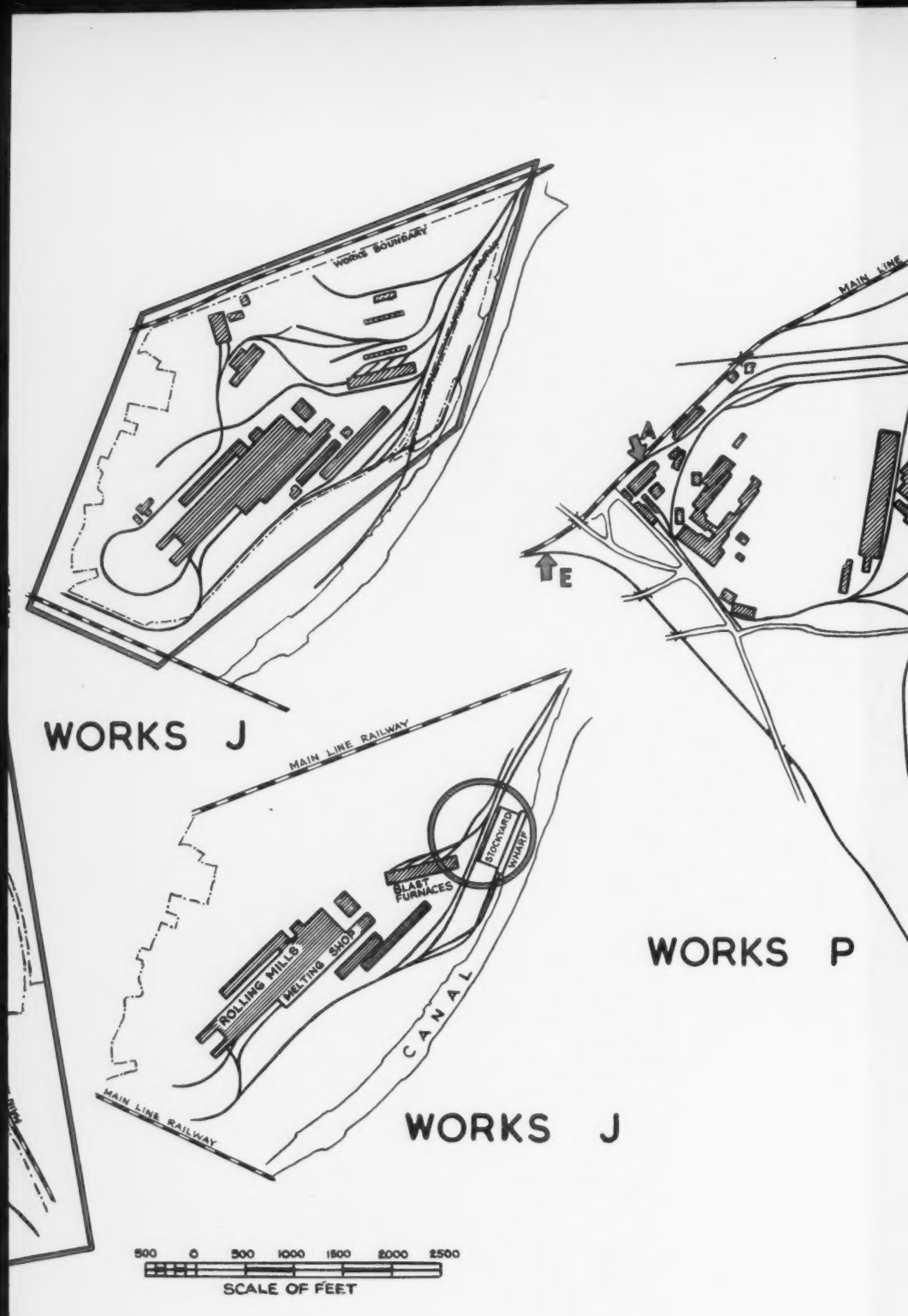
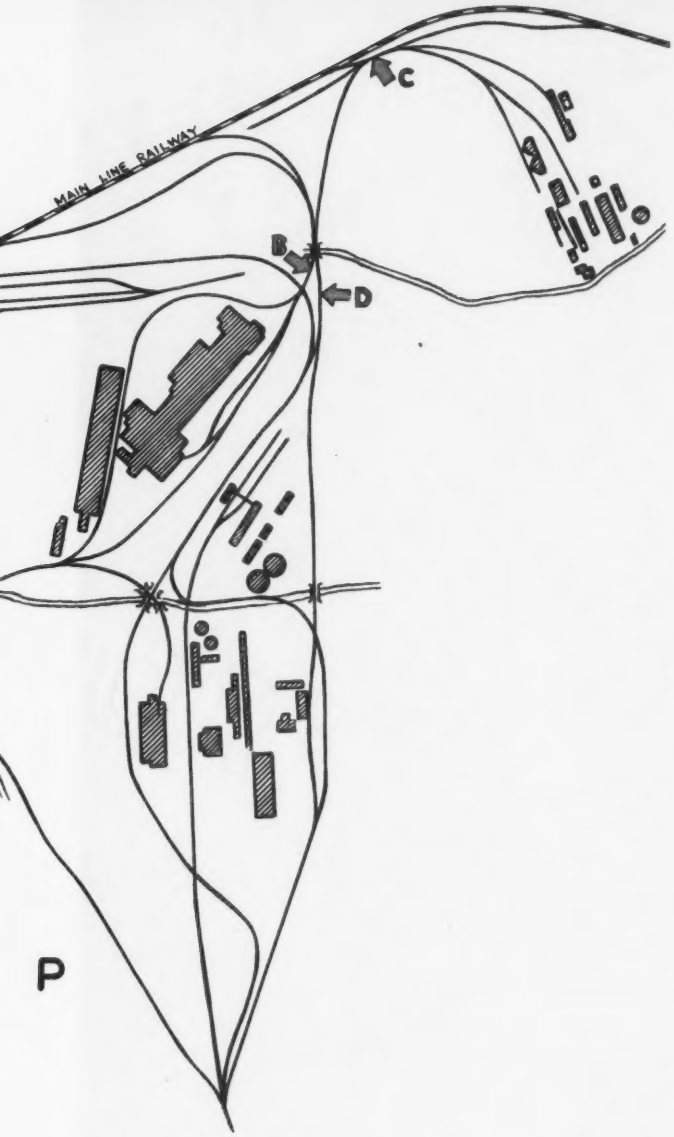
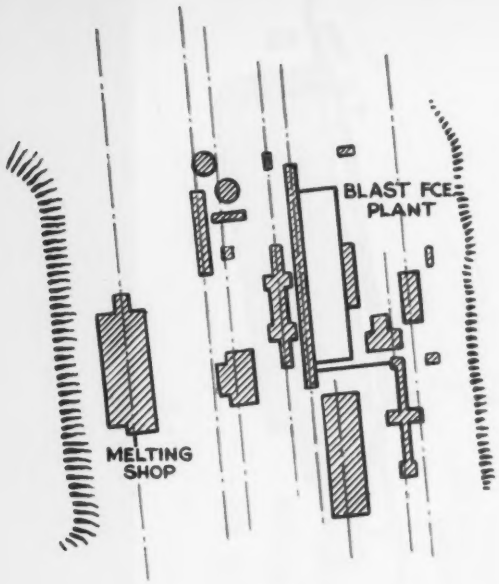


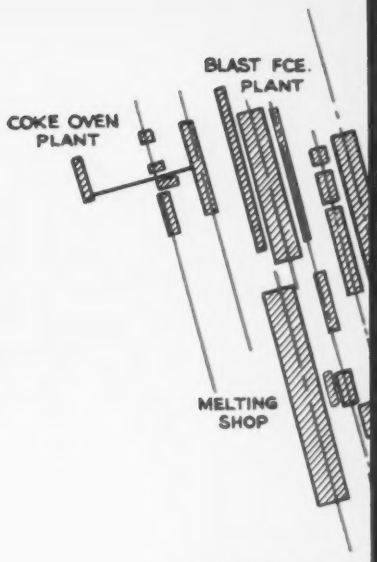
FIG. 4—FACTORS INFLUENCING LAYOUT
(SEE TABLE 4)

FIG. 4

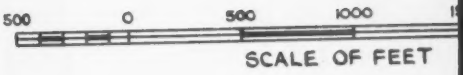


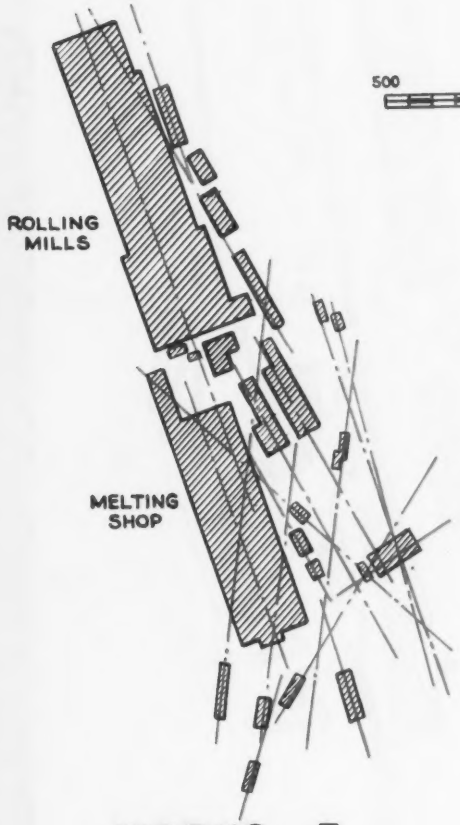


WORKS P



WORKS





WORKS E

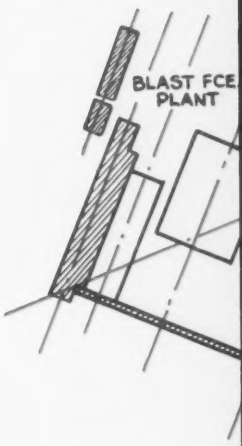
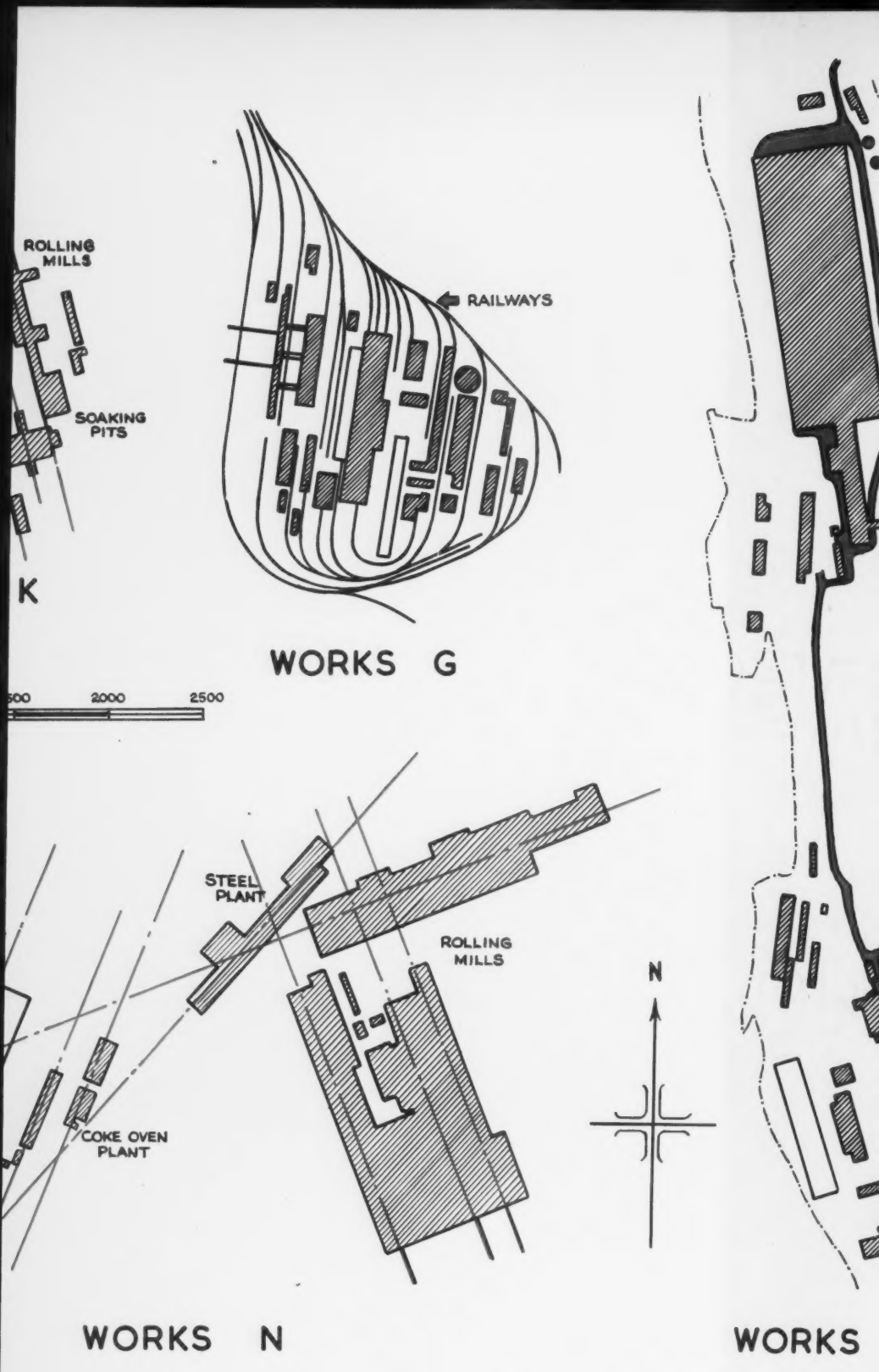
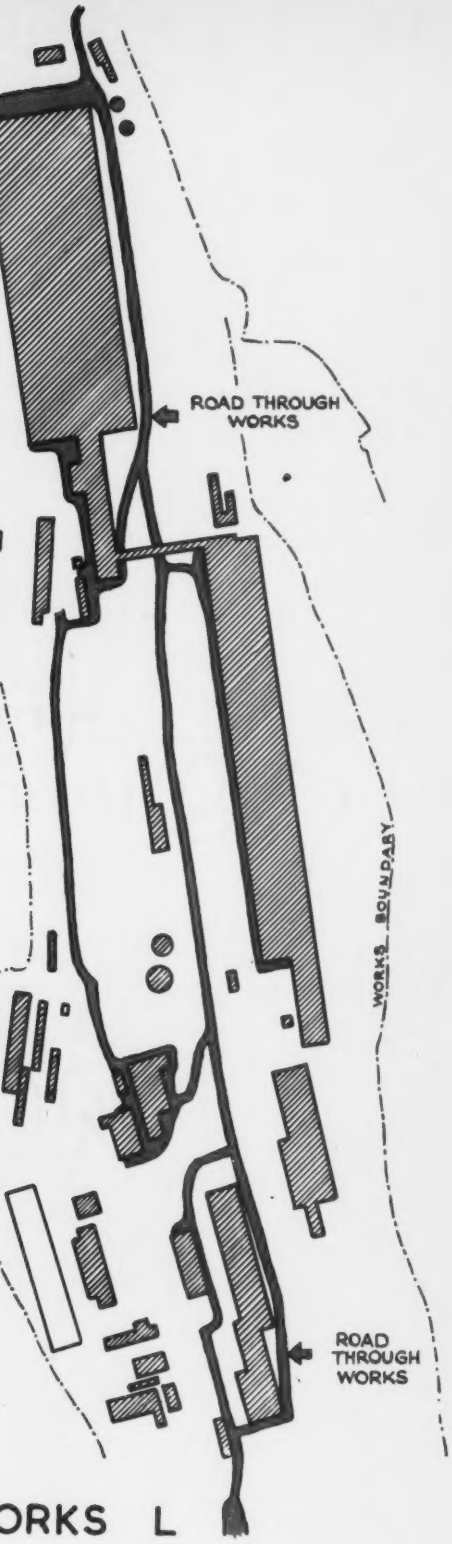


FIG. 5—DISPO



SITION OF BUILDINGS AND PLANT
(SEE TABLE 5)

FIG. 5


ROAD THROUGH WORKS
WORKS BOUNDARY
ROAD THROUGH WORKS
ORKS L

Works	
A	
B	
C	
D	
E	
F	
G	
H	
J	
K	
L	
M	
N	
O	
P	
Q	

APR

Table I

TOPOGRAPHICAL FEATURES

Columns 1 to 12 (*see* also Fig. 2) describe typical examples of features within the boundaries of existing major British integrated works, which have impaired the planning of the layout. Such features and other similar disadvantages should, it is considered, receive greater consideration in the selection of sites for new works.

The condition of ground levels at the sites visited is indicated in columns 13 to 16. General and local ground slopes have proved both favourable and unfavourable to haulage costs. As it is not possible to generalize on these, the net result for any specific instance can be determined only by a detailed traffic survey.

Works	1 Restricted by Subway	2 Severed by Public Railway	3 'Bottleneck' Due to Bridge	4 Works Property Encroaches	5 Roads & House Property encroaches	6 Rail Embankment Crosses Site	7 Slag Heaps on Site	8 Uneven *in situ* Terrain	9 Public Road Severs Site	10 River Severs Site	11 Terraced in Excavation & Fill	12 Severed by Other Works Property	13 Mostly Level	14 Mostly on Slope	15 Local disadvantages	16 Local advantages
A		X											X		——	UP GRADE FOR SLAG
B							X		X	FIG. 2			X		HOT METAL ROAD CIRCUITOUS TO UTILISE RIVER BANK SCRAP SIDINGS AT LOW LEVEL	——
C		X	X					FIG. 2	X		FIG. 2			X	——	DOWN GRADE FOR COAL AND ORE
D	FIG. 2	X											X		HIGH TIP	——
E		FIG. 2											X		UP GRADE TO MELTING SHOP	——
F	FIG. 2		X	FIG. 2									X		UP GRADE FOR ORE	DOWN GRADE FOR SLAG
G					X								X		——	DOWN GRADE FOR COAL
H				X									X		——	——
J				X	FIG. 2	FIG. 2	X						X		UP GRADE FOR FINISHED PRODUCTS, BLAST FCE. AND M.S. SLAG	——
K			X			X								X	UP GRADE FOR RAW MATERIALS	DOWN GRADE FOR FINISHED PRODUCTS
L		FIG. 2		X	X		FIG. 2	X	X		X			X	UP GRADE BY MAIN LINE RLY. FOR ORE, UP GRADE FOR FIN PRODUCTS, SLAG UP MOUNTAIN	DOWN GRADE FOR ORE, COAL, AND SLAG
M			FIG. 2			X							X		UP GRADE FOR ORE AND COKE	DOWN GRADE FOR COAL
N			FIG 2										X		——	DOWN GRADE FOR COAL AND ORE
O	X			X									X		——	DOWN GRADE FOR SLAG
P	X		X	X			X	X	FIG. 2		FIG. 2		X		UP GRADE TO SECTION MILLS FOR INGOTS, RAW MATERIALS AND SLAG ROUTES	——
Q														X	UP GRADE FOR ORE AND COAL	DOWN GRADE FOR FINISHED PRODUCTS

X Denotes existing example

Where a site is accessible by either fresh or salt water, it is very probable that the sub-strata will not form a reliable support for foundations. The extra cost of additional strengthening, such as piling, may therefore have to be set against the advantages of access by natural waterways. Some details of sub-strata are recorded in Table II.

Water Table

The average and maximum height of the water table in relation to the ground level should be carefully considered since it is these levels which determine the maximum depth at which foundation work may be kept dry. Pits forming foundations to plant should, if possible, be built above the water level, and this applies particularly to the checkers in melting shops, which, owing to their internal temperature, are difficult to make watertight. Both the height and the cost of melting shops are particularly affected by this consideration.

Obviously, sites mostly troubled with surface or subsoil water seeping into ducts and pits below ground, are those in valleys and near the seashore ; examples include works *B*, *G*, and *H*. If the subsoil is impermeable, and surrounding ground levels do not promote good surface drainage, even apparently well-placed sites may often be subject to flooding.

Provision for Extension

Allowance for extension must be made when a new works is being laid down, but it is difficult to make long-range forecasts of new developments and so to assess the increase that will be required. For example, it is reasonably certain that the addition of melting shops and mills was not foreseen when the early blast-furnaces were laid down, so that lack of planning and consequent congestion exist in most sites. It is considered, therefore, that, following modern trends, more consideration might well, in future, be given to the aspect of ' planning ahead ' than was probably exercised in the past.

The importance of locating a site in an open area cannot be too strongly emphasized, since lack of space may well prevent a plant from being kept up-to-date. Probable development areas should preferably be reserved to prevent other works from being built and so obstructing future extension. The surrounding natural and artificial features must therefore be considered in the light of whether they are likely to restrict extension. Restrictive features around existing works are described in Table III and are illustrated in Fig. 3.

In general, when a plant is being laid down, provision should, it is considered, be made for an increase of, say, up to 25% in output in the plant. If more is required, then provision should be made for repeating all units on an adjoining area, as discussed later in this paper.

GENERAL PRINCIPLES GOVERNING THE LAYOUT OF AN INTEGRATED WORKS

DEFINITION OF AN OPTIMUM LAYOUT

The best layout is that which enables the various materials to be delivered to their destination in the plant at the time when they are required and as economically as possible, and which enables the finished and waste products to be cleared efficiently. The problem is therefore one of handling materials for the integrated plant as a whole.

If buildings and plant are regularly arranged in the correct sequence to suit these requirements, then it is considered that they will be in the best position to ensure that, excluding the efficiency of the process itself, each unit process is efficiently operated.

ESSENTIAL ARRANGEMENT IN OUTLINE

To enable the foregoing conditions to be realized, material flow lines, considered in their broadest sense as general ' trends,' and not necessarily as individual railway tracks or conveyor systems, should preferably be smooth and without contra-flow. They may therefore change direction in their course through the works, provided that the unit processes are maintained in consecutive order. At any unit process or department, the flow line of each raw material or product should join or leave the main stream without dislocating this stream. In principle, it is considered that contributory streams should, as far as practicable, converge or diverge in the direction of the main flow of material, very broadly as shown in Fig. 6, and should not interfere with one another. This implies avoidance of streams crossing unless

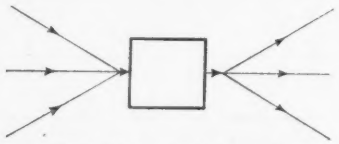


Fig. 6—Essential principle of flow lines

each route can be arranged to be completely independent, as, for example, in the case of a conveyor crossing over or under a railway. As far as possible, traffic to and from each unit process should be segregated from traffic to or from other unit processes or departments.

So far as actual conditions of flow lines in existing works are concerned, these have been ascertained, recorded, and analysed later in this paper, and it will be seen to what extent these diverge from the principles outlined above.

SELECTION OF THE MOST EFFICIENT MEANS OF TRANSPORT

The efficiency and economy with which the materials are transferred between each unit process is dependent upon the means of transport adopted. It is true that the nature of the materials to be handled considerably influences the selection, but a choice may remain. The most suitable method must therefore be chosen, as has also been emphasized in an earlier paper[2] which states that, provided the material to be conveyed is suitable, conveyors or transfer cars or run-ways may in many circumstances be cheaper than rolling stock drawn by steam locomotives on railways.

If, in future, more economical methods are developed, with the result that railways are to some extent superseded, then the basis of design of the layout will be affected, as will be seen later.

Table II

STRATA

Piling occurs in those cases where it normally would be expected, *i.e.*, in river valleys, on estuaries, and on flat sites near the sea. Where the underlying strata is firm, *e.g.*, ironstone, limestone, firm clay, etc., ' spot ' bases have been adopted. Exceptions are works *D* and *E*, where piling might have been expected.

To the date of preparation of this paper, it has been impracticable to obtain more details of strata and variations in ground-water levels.

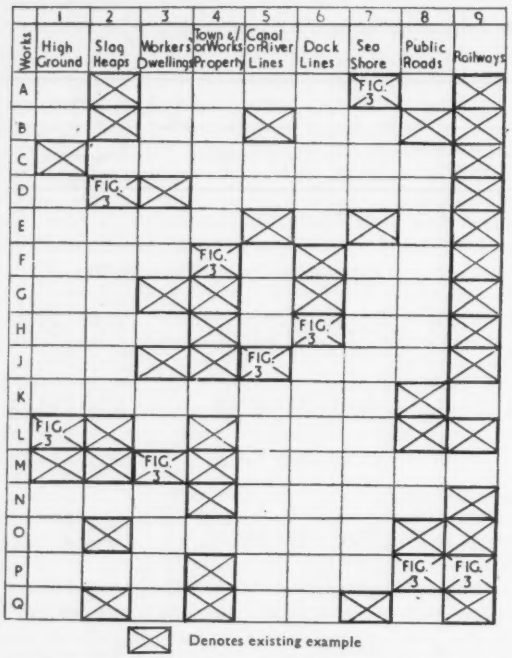
Works	1	2	3	4	5
	Nature of Location	Nature of Surface	Approximate Elevation	Nature of Subsoil	Foundations
A	SEASHORE	MADE-UP	+ 20	SANDY	...
B	RIVER VALLEY INLAND	MADE-UP	+ 30	ESTUARINE LOAM	PILED
C	MOORLAND INLAND	EXCAVATION AND FILL	+ 760	SHALE AND LOAMY CLAY OVER ROCK	' SPOT ' BASES
D	RIVER VALLEY	MADE-UP WITH SLAG	+ 25	CLAY AND SAND	' SPOT ' BASES
E	RIVER ESTUARY AND SEASHORE	MADE-UP WITH SLAG	+ 20	CLAY AND SAND	' SPOT ' BASES
F	RIVER ESTUARY	MADE-UP	+ 20 to 30	CLAY AND SAND	PILED
G	SEASHORE	MADE-UP	+ 20	SANDY	PILED
H	SEASHORE	MADE-UP	+ 20	SANDY	PILED
J	RIVER VALLEY INLAND	MADE-UP OVER SANDY SOIL	+ 40	SANDY CLAY OVER ROCK	PILED
K	INLAND	*IN SITU*	+ 150	SANDY CLAY OVER IRONSTONE	' SPOT ' BASES
L	VALLEY IN MOUNTAINS INLAND	PARTLY *IN SITU*, PARTLY MADE-UP	+ 800 to 900	POOR CLAY OVER ROCK	PILED
M	INLAND	*IN SITU*	+ 60 to 70	SANDY CLAY OVER IRONSTONE	' SPOT ' BASES
N	INLAND	*IN SITU*	+ 310	CLAY AND SAND	PILED
O	RIVER ESTUARY	PARTLY *IN SITU*, PARTLY MADE-UP	+ 16 to 50	SAND	PILED
P	INLAND	SANDY CLAY	+ 60 to 70	SANDY CLAY OVER IRONSTONE	' SPOT ' BASES
Q	SEASHORE	CLAY	+ 20 to 30	SAND AND GRAVEL OVER BLUE CLAY	PILED

Figures in column 3 denote altitudes in feet above Ordnance Survey Datum

Table III

RESTRICTIONS TO EXTENSION

Columns 1 to 9 describe typical examples of features surrounding the boundaries of the existing major British integrated works which are (or could be) potential restrictions to extension. Few existing works have any areas actually adjoining their boundaries which are suitable for accommodating extensions.



FACTORS WHICH INFLUENCE THE LAYOUT OF PLANT

Means of Transport within the Works

Each method of transport, whether it be locomotives and rolling stock on tracks, conveyors, transfer cars, transporters, 'trams,' telpher cars, or travelling ropeways on overhead runways, has its own advantages and disadvantages and must be selected on its own merit for any specific duty. Each, however, has its limitations in the way in which it can be arranged on plan, and this automatically affects the layout.

In iron and steel works, railways have been the principal means of transport and will, it is considered, continue to be so for some time to come. The layout will therefore also continue to be governed by the limitations of railway transport. This degree of limitation applies particularly in the case of railways where the major factor is the problem of changing direction. With a conveyor system, for example, a change of direction through any angle creates no difficulty, and is effected by the transference of the material from one conveyor to another.

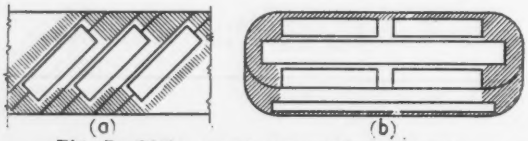


Fig. 7—Oblique and rectangular systems

In the case of railways it is primarily desirable that the radius of curvature of bends should be maintained as large as possible to avoid wear and strain on the locomotives and rolling stock. This matter of radius of curvature is important because there are often lengths on a curve which, owing to bad track laying, are very sharply curved—comparable with the junction of two straights at an angle. If the average radius is already small, then locally the radius will be smaller, and such conditions frequently result in derailments. Turns through small angles of the order of 45° are preferable, as in the well-known 'diagonal' configuration of approaches to sidings. Right-angled turns are not precluded, but they cannot be effected sharply and should be made only at a prescribed minimum radius. They are also liable to produce 'blind' corners if buildings are placed near the line. The introduction of right-angled turns, however, enables a 'ring' or 'belt' system to be established around the works, often with beneficial results. Briefly summarized, the two turns (45° (approximately) and 90°) give rise to two reasonably distinct formations described later in this paper, namely, the oblique 'herringbone' or 'diagonal' system in Fig. 7*a*, and the rectangular 'belt' or 'ring' system in Fig. 7*b*.

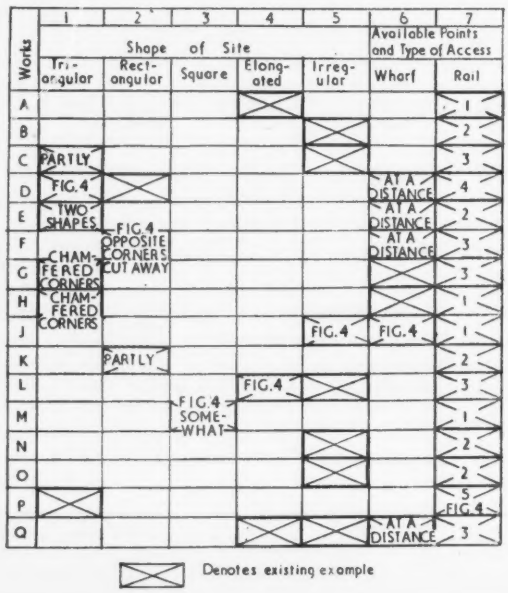
Concerning their relative merits, consideration

Table IV

FACTORS INFLUENCING LAYOUT

Columns 1 to 5 indicate the approximate shape of site of the major British integrated works. Irregularity and asymmetry in the layout is often the result of irregularities in the boundary of the site available (apart from other reasons dealt with elsewhere).

Columns 6 and 7 indicate the type of access and approximately the number of points of access. One access is considered to be insufficient, as at works *M*, where all unit processes have been skewed to suit the one point of access. Where there is access by water, ore has often to be transferred initially into wagons instead of being discharged directly into the stockyard.



shows that each individually has advantages and neither is wholly superior to the other. Some space in both systems is difficult to develop and is often wasted. In Fig. 7*a* there are the ' tapered ' ends, and in Fig. 7*b* the ' sectors ' are bounded by the right-angled curves.

Satisfactory layouts of drainage and water systems are important and for these neither system shows a marked advantage. The herringbone arrangement has the merit of conforming to the general principle of maintaining smooth flow lines, which are not outstanding in the belt system. Other factors can be used as a basis of comparison, but these will be dealt with under their appropriate headings.

Examples of both systems exist at the well-known Gary Works (Indiana) and at Hütte Braunschweig (Germany), the herringbone system being mostly in evidence at three new works now being built or planned.

Shape of Site

The shape of the site obviously affects the way in which the plant can be arranged. Existing sites range from square or circular to elongated-rectangular or triangular-shaped figures in plan, and these are recorded in Table IV.

The best form for development cannot be assessed until the various possible arrangements of plant have been considered, and this is investigated in the section entitled "Comparative Analysis of Layouts for an Integrated Iron and Steel Works." Without entering into any of the reasons here, it is considered that the shape of a site for a new works should preferably be a well-proportioned rectangle.

Available Points and Types of Access

In view of the large quantities of iron ore, coal, and scrap used in an integrated works, the impression was gained, during the course of the visits, that it might be more satisfactory if these materials were provided with separate points of access to the site, but this view is not generally held. The best practice may be summarized briefly as follows :

Arrangements for the receipt and despatch of all materials by rail should broadly include holding-sidings close to each department (or unit process) of the works, with segregated routes for traffic between these holding-sidings and the main incoming and despatch exchange-sidings (through which access is obtained to the main railway system). The incoming and despatch exchange-sidings should preferably be separate and each should have not less than two points of contact with the main railway system. The number of tracks at each point of contact with the main railway system will depend on the quantity of the materials to be handled ; one track at each point of contact may be sufficient.

Where ore is transported by water, it seems axiomatic that the advantage of comparatively cheap freight rates will be lost if the ore has to be double-handled by being off-loaded into railway wagons. It should therefore preferably be possible for the ore to be deposited directly into the stockyard or alternatively into the grabbing-trough attached thereto.

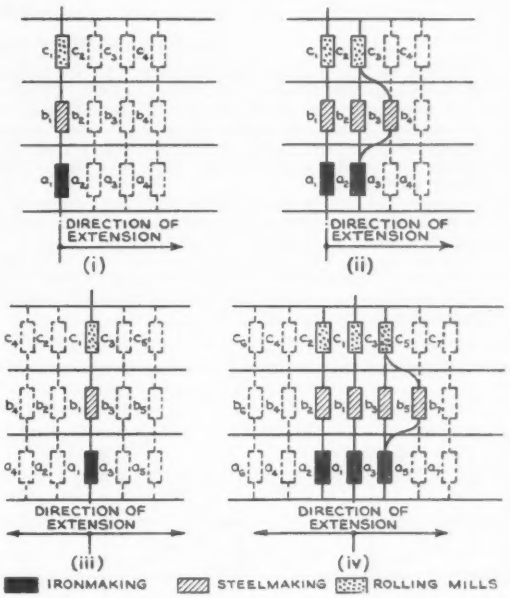


Fig. 8—Multiple Units—Basis of suggested layouts

Conditions in existing works concerning the shape of site and available points and types of access considered in the foregoing paragraphs are reviewed in Table IV and illustrated in Fig. 4.

DISPOSITION OF BUILDINGS AND PLANT

To achieve the optimum layout defined above, the arrangement of the individual items of buildings and plant and of the unit processes (or departments of the works) should be such as to induce an ordered flow of material through the works, and they should therefore, it is considered, be parallel to, or at right-angles to, defined axes of the whole works, as described and illustrated in Table V and Fig. 5. All buildings and plant should be accessible by roads and railways, which should be arranged parallel to the defined axes of the works.

The regular disposition of buildings and plant is required primarily for the purpose of the planned flow of materials through each unit process, but there is also the important consideration referred to in the following paragraph.

It is recommended that the axes of buildings and plant and also those of unit processes, should conform to the axes defined above, even at the expense of some filling or excavation which may be necessary, because if a simple regular plan is not adhered to, the layout tends to become confused and it is then often difficult at a later stage to utilize the remaining space to the best advantage. A comparison of the layout features of existing works is given in Table V and illustrated in Fig. 5.

BASIS OF SUGGESTED LAYOUTS

Before turning attention to features of each of the unit processes separately, the composition of the works as a whole should be considered. In this, each main department or unit process, namely,

Table V

DISPOSITION OF BUILDINGS AND PLANT

Columns 1 and 2 describe broadly the arrangement of individual items of plant relative to the axes of their unit processes in existing works. In general, items of plant are regularly arranged relative to at least one axis of setting out of the unit processes.

Columns 3 and 4 describe broadly the arrangement of unit processes relative to the works as a whole, in existing works. Unit processes are, for the most part, at various angles to one another and are irregular. Only a few works have any discernible axis of setting out, and none has any symmetry about two axes.

Columns 5 and 6 describe broadly the extent to which metalled roads are provided in existing works. In general the provision of road access is either negligible or partial. Only one or two works are notable for their road systems.

Columns 7 and 8 describe broadly the arrangement of rail systems in existing works. With the exception of works *G*, no wholly planned system, comparable with Hütte Braunschweig or Gary, exists. Rail systems have invariably been extended and improvised from time to time. Figure 5 gives typical examples.

Works	Individual Items of Plant Relative to Axes of Unit Process		Unit Processes Relative to Axes of Works		Metalled Roads		Railways	
	Regular 1	Irregular 2	Regular 3	Irregular 4	Provided 5	None 6	Regular 7	Irregular 8
A	⊠		⊠			⊠	⊠	
B	⊠			⊠	PART	PART		⊠
C	MOSTLY			⊠	PART	PART		⊠
D	PART	PART		⊠		⊠		⊠
E		FIG. 5 PART		⊠	⊠			RADIATE
F	MOSTLY		MOSTLY		PART		BELT	
G	⊠		⊠		PART	PART	FIG. 5 BELT	
H	PART	PART	PART			⊠	BELT	
J				⊠	PART	PART		⊠
K	MOSTLY	PART	FIG. 5 PART	PART		⊠	PART	PART
L	⊠		PART	PART	FIG. 5			ELONGATED
M	⊠			RADIATE		⊠		RADIATE
N	MOSTLY			FIG. 5	⊠			RADIATE
O	MOSTLY	PART		⊠	⊠			⊠
P	FIG. 5 MOSTLY			⊠	MOSTLY		PART	PART
Q	MOSTLY			⊠	PART	PART		ELONGATED

⊠ Denotes existing example

ironmaking, steelmaking, and rolling mills, comprises one or more units each of optimum size, $a_1 a_2 a_3$, etc., $b_1 b_2 b_3$, etc., $c_1 c_2 c_3$, etc., as in Fig. 8. Each succeeding unit (for example, b_1 relative to a_1, and c_1 relative to b_1) should be capable of receiving and consuming the product of the preceding unit, so preserving a balance in their output. Provision for variations in the 'through-put' of the units, and modifications to optimum sizes of units due to practical considerations, are discussed in the section "Comparative Analysis of Iron and Steel Works" and in the "Conclusions," and are illustrated in Figs. 8, 16, and 17.

IRONMAKING (BLAST-FURNACE) PLANT

RAW-MATERIALS RECEPTION

A variety of methods of raw-materials reception is in operation in Great Britain owing to the various ways in which the sites have been developed in course of time. A brief survey of existing arrangements is given in Table VI and can be seen in plan in the material flow diagrams in Figs. 18 to 22.

Arrangements for the reception of ore and limestone are complicated by numerous factors which include the use at any one works of a large number of ores from both home and overseas and the fact that these may require careful preparation and blending before and after stocking. It is therefore impracticable at this stage to put forward firm recommendations to suit all conditions. It is possible, however, to make some observations on specific arrangements of plant and methods of handling and these may help to ventilate some of the problems. Figure 9 has been prepared merely to assist in describing the points made in the text, and it is stressed that these arrangements are not intended to be taken as necessarily the best to be followed.

Water-Borne Ore

Where ore is transported by water, as in the case of foreign ore, it is considered, subject to the satisfactory location of the ore-treatment plant, that there must be an appreciable saving in cost if the ore can be received whenever possible (*i.e.*, when it is not necessary to crush, screen, and blend it) directly into the stockyard from an adjoining wharf, in some way comparable with Figs. 9*a* and 9*b*, without being first loaded into wagons and hauled some distance by locomotive before arriving at the stockyard.

Even if ores from overseas are chiefly used, provision for the reception of home ores by rail will also have to be made. Considering for example the arrangements shown in Figs. 9*a* and 9*b*, the rail sidings will have to be situated beyond the high-line bunkers (on the side remote from the dock) and the ore transferred by conveyor to the stockyard (or crushers, etc.). As an alternative, it might be possible to bring one track along the edge of the wharf for discharging wagons into the grabbing-trough. There is, however, obviously no room for more than about one track on the edge of the wharf (between the grabbing-trough and the dock) so that the ore holding-sidings will have to remain on the 'far' side of the high-line bunkers, as described above.

Where there is access by water, it is of course axiomatic that the approaches to the wharf should have adequate width and depth. Certain existing waterways do not conform to this; in one instance, ships have to discharge part of their burden for conveyance by rail before negotiating the waterway with the remainder of their cargo, and in two other instances the size of the vessels is closely limited by the depth of water available in the dock. Regarding accommodation at the wharf, means should be provided to enable ships to be rapidly unloaded at any point along the length of the stockyard, *i.e.*, along the wharf. For example, the unloaders should discharge into travelling weighing hoppers which in turn may discharge into either a grabbing-trough or a transfer car. The unloaders should be separate from the ore bridge so that the ore may be transferred to its requisite position in the stockyard, if necessary, after the ship has sailed.

Rail-Borne Ore

The broad principle of rail layout has been described in an earlier section under "Available Points and Types of Access" (*q.v.*), and from this it follows that the most suitable position for the holding-sidings must be found. Where there is only rail access, sidings immediately adjoining the stockyard, as in Figs. 9*c* and 9*d*, appear to be the most logical. Where there is also water access, the arrangements in Figs. 9*a* and 9*b* seem to be the simplest alternatives.

Wagons should preferably be fed through the tipplers by gravity, attention being paid to the magnitude of the gradients, which must be sufficient to induce movement in the rolling stock under most weather conditions, a suitable gradient being of the order of 1 in 100. Comparable arrangements to this include the use of winch and capstan or mechanical mule to withdraw the wagons from the sidings to the tippler and then the use of gravity for disposal of the empty wagons. Gravity sidings can be arranged locally, where required, in the site, similar to the 'humps' used in railway marshalling yards; the site as a whole can be generally level.

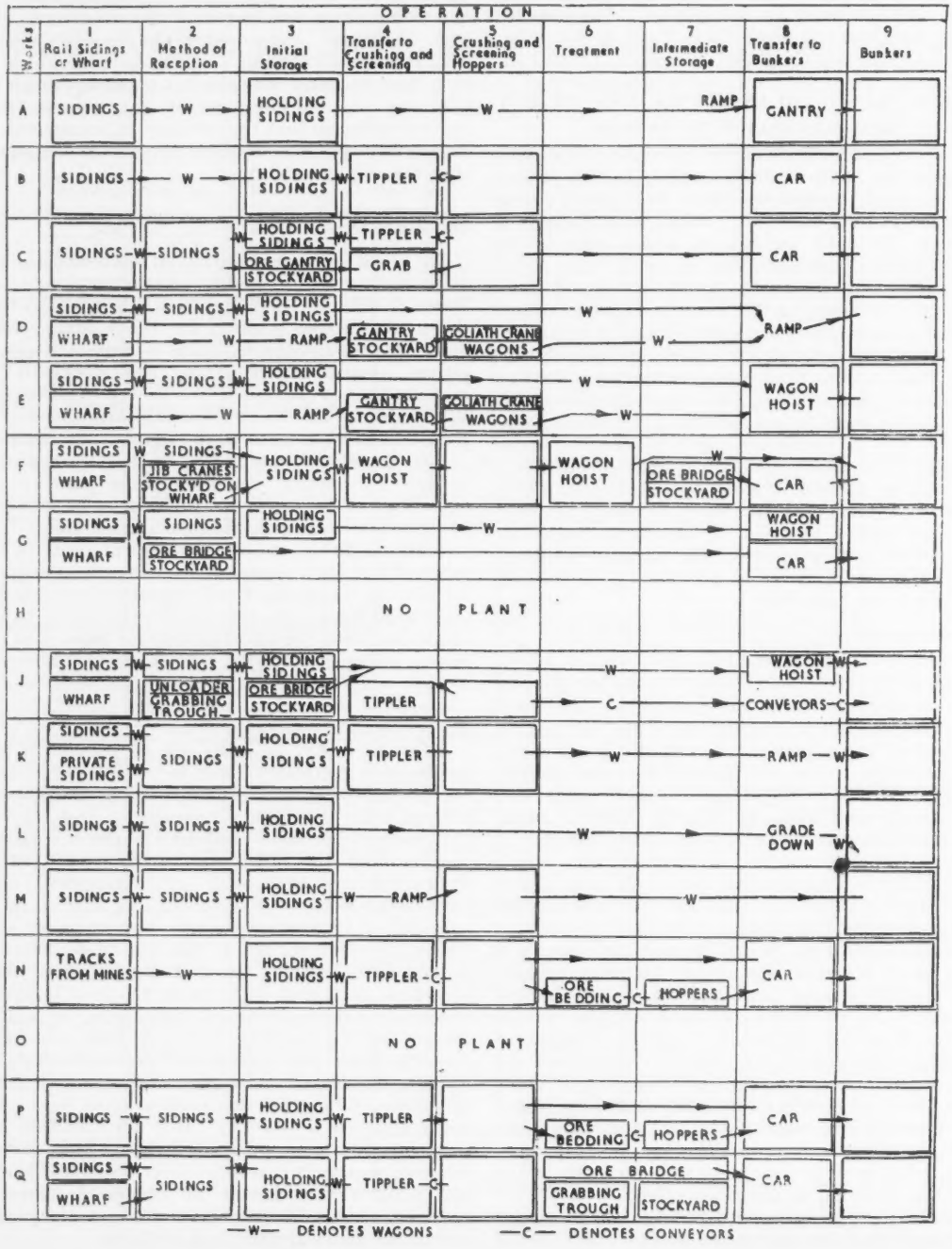
Although it will probably not be possible in the holding-sidings (though it may be possible in the main exchange-sidings), the most favourable condition to achieve is for the railway company to push wagons in at one end and also to withdraw empty or outgoing wagons from the other end, without the use of works locomotives. Such an arrangement does exist at one works.

It is not economical to use ore wagons or coal wagons for storage, but if this has to be adopted owing, for example, to irregular supplies, then consideration should be given to the installation of temporary sidings, some of which may be widely spaced, having stocking areas on both sides and separate from the normal ore or coal reception-sidings. In view of the continued abnormal delivery conditions, sidings for this purpose have become in many instances a necessity. It is not intended that the temporary sidings described should form part of the usual materials-handling equipment, but if labour and plant cannot handle an abnormal influx of material, serious difficulty arises if the works cannot accept the material when it is available.

Table VI

ORE HANDLING (1)

The features described in columns 1 to 9 may be followed on the material flow diagrams, Figs. 18 to 22. Works *B*, *C*, *J*, *N*, *P*, and *Q* all have good arrangements in principle, although the stockyard is located away from the bunkers in the cases of works *J* and *Q*, and the tare weights of the wagons are lifted in the wagon hoist at works *J*. Tare weights of wagons are lifted by ramp, wagon hoist, or tippler, at works *D*, *E*, *F*, *G*, and *M*. The stockyard is located away from the bunkers in works *D* and *E*. No stockyard is available at works *M*.



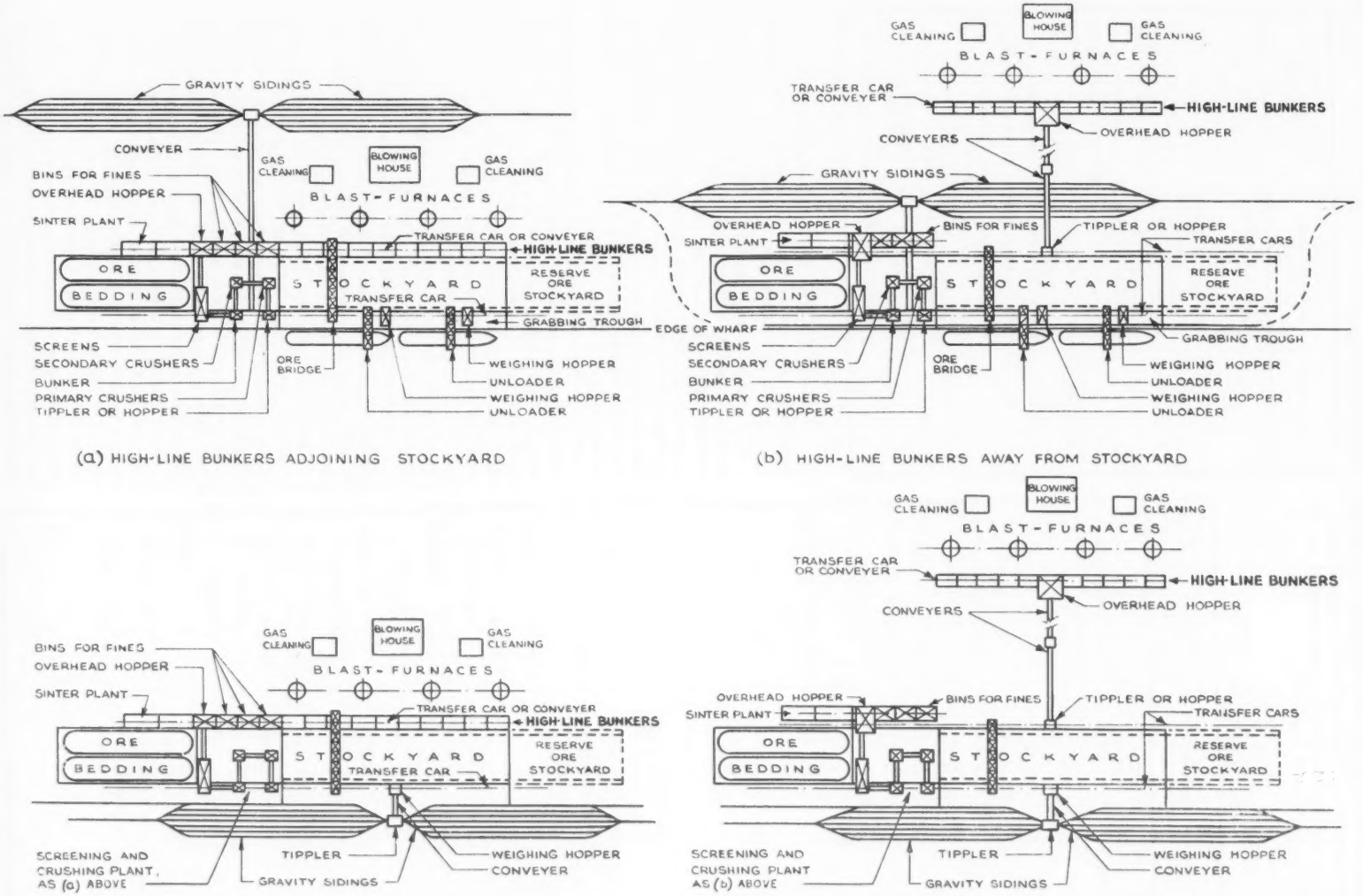


Fig. 9—Ore reception (*a*) and (*b*) by both water and rail, (*c*) and (*d*) by rail only

Limestone and other blast-furnace materials, with the exception of coal and coke, should preferably be received, transported, and stocked in the ore-handling plant and stockyard.

Table VII
ORE HANDLING (2)

LAYOUT	BY-PASSING SCREENS AND CRUSHERS	PASSING THROUGH SCREENS AND CRUSHERS
ARRANGEMENT ILLUSTRATED IN FIG. 9*a*	SHIP UNLOADERS WEIGHING HOPPER GRABBING TROUGH ORE-BRIDGE GRAB STOCKYARD ORE-BRIDGE GRAB TRANSFER CAR (OR CONVEYORS) HIGH-LINE BUNKERS	SHIP UNLOADERS WEIGHING HOPPER GRABBING TROUGH ORE-BRIDGE GRAB TRANSFER CAR TIPPLER (OR HOPPER) CRUSHERS SCREENS — Fines → SINTER PLANT OVERHEAD HOPPERS TRANSFER CAR (OR CONVEYORS) STOCKYARD (Ore-Bridge Grab Casting Back) — HIGH-LINE BUNKERS
ARRANGEMENT ILLUSTRATED IN FIG. 9*b*	SHIP UNLOADERS WEIGHING HOPPER GRABBING TROUGH ORE-BRIDGE GRAB STOCKYARD ORE-BRIDGE GRAB TRANSFER CAR TIPPLER (OR HOPPER) CONVEYORS OVERHEAD HOPPER TRANSFER CAR (OR CONVEYORS) HIGH-LINE BUNKERS	SHIP UNLOADERS WEIGHING HOPPER GRABBING TROUGH ORE-BRIDGE GRAB TRANSFER CAR TIPPLER (OR HOPPER) CRUSHERS SCREENS — Fines → SINTER PLANT OVERHEAD HOPPERS TRANSFER CAR STOCKYARD (Ore-Bridge Grab Casting Back) — TIPPLER (OR HOPPER) CONVEYORS OVERHEAD HOPPER TRANSFER CAR (OR CONVEYORS) HIGH-LINE BUNKERS
ARRANGEMENT ILLUSTRATED IN FIG. 9*c*	RAILWAY WAGONS TIPPLER WEIGHING HOPPER TRANSFER CAR STOCKYARD ORE-BRIDGE GRAB TRANSFER CAR (OR CONVEYORS) HIGH-LINE BUNKERS	RAILWAY WAGONS TIPPLER CRUSHERS SCREENS — Fines → SINTER PLANT OVERHEAD HOPPERS TRANSFER CAR (OR CONVEYORS) STOCKYARD (Ore-Bridge Grab Casting Back) — HIGH-LINE BUNKERS

Table VII (*continued*)

LAYOUT	BY-PASSING SCREENS AND CRUSHERS	PASSING THROUGH SCREENS AND CRUSHERS
ARRANGEMENT ILLUSTRATED IN FIG. 9*d*	RAILWAY WAGONS TIPPLER WEIGHING HOPPER TRANSFER CAR STOCKYARD ORE-BRIDGE GRAB TRANSFER CAR TIPPLER (OR HOPPER) CONVEYORS OVERHEAD HOPPER TRANSFER CAR (OR CONVEYORS) HIGH-LINE BUNKERS	RAILWAY WAGONS TIPPLER WEIGHING HOPPER TRANSFER CAR TIPPLER (OR HOPPER) CRUSHERS SCREENS — Fines → SINTER PLANT OVERHEAD HOPPERS TRANSFER CAR TIPPLER (OR HOPPER) STOCKYARD (Ore-Bridge Grab Casting Back) — CONVEYORS OVERHEAD HOPPER TRANSFER CAR (OR CONVEYORS) HIGH-LINE BUNKERS

THE HANDLING OF RAW MATERIALS

Handling Plant for Ore and Limestone from Sidings (or Wharf) to High-Line Bunkers

The whole system should be flexible and should enable the ore to be crushed, screened, sintered, and blended, as and when necessary, before deposition in the stockyard or in the high-line bunkers, and also, if required, after being taken out of the stockyard.[3, 4] The possible variations in the sequence of operations for the arrangements of plant considered in Fig. 9 are indicated in Table VII.

Tipplers for ore, should, as far as practicable, be built at ground level to avoid raising the tare weights of wagons up ramps, as for example, appears to be necessary to accommodate the crushers which are used for home ore. The waste of energy in raising rakes of wagons up ramps by means of locomotives has already been stressed.[2]

Although the tare weights of wagons may be counterbalanced in wagon hoists and wagon drops, the authors question whether the use of these is correct in principle rather than discharging the load roughly at ground level and raising the burden by conveyors or perfectly balanced skip hoists.

Ramps for the use of locomotives and wagons should be avoided because the limiting grade causes them to be extended across the site, with plan width of side slopes of bank (where filled banks are used) corresponding to their height, and with the result that they dissect and encumber the site. Even with framed gantries in lieu of banks the same objection remains.

Where tracks are provided over high-line bunkers for regular use, some consider that access at both ends should be provided to facilitate removal of the empty wagons. Blast-furnace traffic is too infrequent to justify the expense of a second ramp, and, also, with two ramps, the wagons have to be propelled over a long length of track. Access at one end should therefore be adequate.

Coal

It is not considered necessary to review in detail the arrangements for the transfer of coal from the wharf or tippler at the incoming sidings to the coke ovens and thence to the high-line bunkers, because the use of conveyors is now widely adopted and this is considered to be the most satisfactory method.

Facilities for the reception of coal, very similar to those for ore, must be provided. In all the existing works that have been visited, transport between coal tippler and coke ovens is by conveyor, and transport between coke ovens and high-line bunkers is by means of conveyor, with the exception of the following: Railway wagons at works *D* and *G*, 'trams' on a continuous ropeway at works *M*, and partly railway wagons and partly conveyor at works *C*.

Facilities for the reception of bought coke should include a tippler, and conveyor access to the main conveyor system carrying coke from the coke ovens to the high-line bunkers. Some authorities, however, prefer the transfer of coke to the high-line bunkers direct by railway wagon in order to minimize breakage, but in the authors' view every effort should be made to avoid raising and lowering wagons to and from the top of the high-line bunkers. Transfer by railway wagon for direct discharge into the high-line bunkers should therefore be used only in cases of emergency.

Raw-Materials Stockyard

The requisite sizes and relative location of the main and reserve stockyards, together with the methods of filling and unloading them, are integral with the whole subject of ore reception and were referred to at the beginning of this section; these accordingly warrant further consideration before formal recommendations can be made. However, concerning the relative position of stockyard and high-line bunkers, opinion is still divided; on the one hand, in the event of a major breakdown in the crushing plant or in supplies because of severe weather conditions, the presence of the stockyard immediately behind the high-line bunkers is a positive reassurance for the maintenance of output; on the other hand, taking the view that all the ore in the stockyard is not usually handled directly by the ore-bridge grab into individual furnace bins, but more generally into transfer cars, it is possible by employing high-capacity transfer cars to have the ore stockyard arranged at some distance from the high-line bunkers. If necessary, conveyors may also be used, somewhat as in Figs. 9*b* and 9*d*.

Opinion—which for the most part is also favoured by the authors—is that the most convenient position for the stockyard is immediately behind the high-line bunkers, as shown in Figs. 9*a* to 9*d*, using: (i) An ore-bridge grab and transfer car, (ii) a 'Demag' hopper on a travelling cross-bridge, (iii) a reclaimer with 'underground' and inclined conveyors, or (iv) a fast overhead travelling crane on a gantry with grab, in lieu of the conventional ore-bridge referred to in item (i).

In regard to capacity, the stockyard must be sufficiently large to accommodate the various qualities and types of ore and limestone. Individual heaps must be separate, allowing for variations in the angles of repose. They must be accessible for rapid transfer to any bunker with the minimum of handling. Owing to the variety of types of ore and the variations in

Table VIII

RAW-MATERIALS STOCKYARDS AND STOCKING GROUNDS

The sizes of stockyards and stocking grounds in the major British integrated works are shown, together with the relationship of the stockyards and stocking grounds to the wharves and sidings from which they are fed, and to the high-line bunkers which they themselves feed. Figured dimensions are stated only to convey some idea of the extent of area occupied, and not necessarily of the capacity.

Works	Main Stockyard (Area Occupied)	Other Stocking Grounds	Relation of Stockyard and Stocking Grounds To:		
	Approx. Size, ft.	Approx. Size, ft.	Wharf	Sidings	High-Line Bunkers
A	400 × 100	...	...	...	AT END OF MAIN BUNKERS
B	730 × 600	...	SEPARATE, AT CONSIDERABLE DISTANCE	SEPARATE	ADJOINING
C	500 × 300	UNDEFINED	...	SEPARATE	ADJOINING
D	1600 × 100	1120 × 60 (ORE) 1150 × 130 (GENERAL)	SEPARATE	...	SEPARATE
E	750 × 100	...	SEPARATE	...	SEPARATE
F	400 × 100	UNDEFINED (NEXT TO WHARF)	MAIN STOCKYARD SEPARATE, ADDITIONAL STOCKYARD ADJOINING	ADJOINING	ADJOINING
G	700 × 140	UNDEFINED	ADJOINING	SEPARATE, AT SHORT DISTANCE	ADJOINING
H	...	...	...	...	...
J	600 × 200	UNDEFINED	ADJOINING	ADJOINING	SEPARATE
K	UNDEFINED	...	SEPARATE, AT CONSIDERABLE DISTANCE	ADJOINING	SEPARATE
L	725 × 150	UNDEFINED	SEPARATE, AT CONSIDERABLE DISTANCE	SEPARATE, AT SHORT DISTANCE	ADJOINING
M	NONE	NONE	...	...	...
N	575 × 140	...	...	SEPARATE	ADJOINING
O	NONE	NONE	...	...	...
P	775 × 175	VARIOUS, OTHERS UNDEFINED	...	ADJOINING	ADJOINING
Q	780 × (180 + 30)	UNDEFINED	SEPARATE	ADJOINING	SEPARATE

relative quantities of each, it is not possible to estimate the area of stockyard required for any given steel output without knowing the classes of ore to be expected and the quantities of each. This is a quantitative question which, as mentioned in the introduction to this paper, would require to be the subject of further investigation. The longitudinal retaining walls on which the ore-bridge track is carried should be as high as possible to enable the ore piles to be heaped against them so as to minimize loss of storage volume at the end of each pile.

Pending a more detailed investigation into the capacities of stockyards, the general consensus of opinion is that the centre to centre of the ore-bridge or gantry crane rails should preferably be at least 200 ft.

Where the stockyard adjoins a waterway, a grabbing-trough is considered necessary; where the stockyard is fed from railway wagons the grabbing-trough is of course unnecessary, its place being taken by the tippler and conveyor (*see* Figs. 9*c* and 9*d*).

To prevent ore, stone, and coke from becoming frozen during cold weather in stockyard and bunkers, consideration might be given to the use of low-grade heat.

An idea of the extent of stockyard areas for raw materials in existing works is given in Table VIII.

Raw-Materials Stocking Grounds

Stocking grounds for the storage of reserve stocks of ore and limestone are desirable. In existing works the location of these areas is dependent on local site conditions. As they are not in such constant use as the main stockyard, grabs on mobile steam cranes have been used in lieu of an ore-bridge, a crane, or a fast travelling gantry crane.

In the authors' opinion, the reserve stockyard should form an addition to the normal length of stockyard so that the reserve stock can also be handled by the ore-bridge crane and transfer cars. Thus the normal length of stockyard will correspond to the design capacity plus some margin of, say, 10%, whilst the additional length of, say, another 40% will carry the reserve stocks. It will be appreciated that these percentages are not fixed, but are considered to be possible values depending on the results of further investigation on a quantitative basis.

Areas allocated to stocking grounds for raw materials in existing works are noted in Table VIII.

Continuous Filling of Ore to the Stockyard

Consideration might be given to the development of continuous filling of the ore stockyard, similar to coal-handling plant at power stations, in lieu of the transfer car and ore-bridge grab. The weighing hopper would pass the ore to a long-travelling conveyor and thence on to the cross-bridge which would discharge from a hopper passing to and fro across the stockyard, similarly to the arrangement adopted for a bedding plant. The grabbing-trough would still be required for ore which is in process of being unloaded by the unloader, and which is temporarily in excess of the capacity of the conveyor. The remainder of the shipload could then be lifted from the grabbing-trough after the ship had sailed and could subsequently be passed by the same route to the stockyard, namely by hopper, longitudinal conveyor, and cross-conveyor on the bridge.

Transfer of Ore from Stockyard to High-Line Bunkers

Consideration might be given to the development of a reclaimer with underground conveyors for removing the ore from the stockyard. Such an arrangement would be similar in principle to the type used for a bedding plant. The ore would then be carried direct by tripping conveyor to the appropriate high-line bunker. This method has a successful example in the 'underground' conveyors used for reclaiming of coal stocks in some power stations, and is understood to be used at Fontana Steelworks for ironmaking and steelmaking, miscellaneous materials, and for sinter. The speed and efficiency of the arrangement would have to be proved against a fast long-travelling crane fitted with a grab.

Coke Ovens and By-Products Plant

The coke ovens and by-products plant should be reasonably spaced from the blast-furnace plant so as to avoid restricting the arrangement of the stoves, primary dust catchers, etc., but sufficiently near to be within a moderate distance for conveyor access to the high-line bunkers.

The coke ovens should be placed as closely as possible to the point at which the coal enters the site. This requirement is particularly necessary where coal is conveyed by water.

When determining the position of the by-products plant, due consideration should be given to the fire risk. 'Through' locomotive tracks should not be laid near the benzol plant.

The transfer of the raw coal from the tipplers to the coke ovens, and of the coke from the coke bench or wharf to the high-line bunkers, should preferably be effected by a system of conveyors. As mentioned under the heading of "Coal," bought coke, after being tipped from the railway wagon, should be transferred by conveyors to the main conveyor system which is passing coke from the coke ovens to the high-line bunkers.

From the point of view of arranging smooth flow lines to converge into the high-line bunkers and thence out to the blast-furnaces, it appears more correct in principle for the coke ovens and by-products plants to be situated either on the stockyard side of the high-line bunkers or at either end of the bunkers. However, as coal more usually arrives by rail, it may be more convenient to locate these two plants on the 'front' side of the blast-furnaces, beyond the rail tracks attached to the blast-furnaces; in this case, the coke has to take what is virtually a 'contrary' route past or through the blast-furnaces in order to arrive at the high-line bunkers, and this would appear to contravene a good principle of maintaining smooth flow lines.

The location of the coke ovens and by-products plant in relation to the high-line bunkers in existing works is summarized in Table IX.

High-Line Bunkers

The position of the high-line bunkers relative to the blast-furnaces is determined by the charging arrange-

Table IX

COKE OVENS AND BY-PRODUCTS PLANT

Coke ovens should preferably be near the intake of materials (or the site ' entrance '); columns 1 to 3 give some indication of how far this is achieved. They should also preferably be near the high-line bunkers, and to be in the correct sequence should occur in quadrants III or IV in Fig. 10. If they are situated in quadrants I or II, then the material is being transported against the main flow of materials. Where the materials are transported by conveyor, however, this may be satisfactory.

The distances given are approximate and are measured direct on plan. Where the route indicated in columns 3 and 7 is circuitous, the actual length of the route is considerably greater. Actual locations can be seen on the material flow diagrams, Figs. 18 to 22.

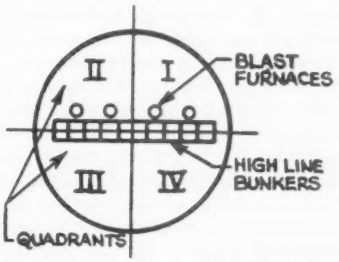


Fig. 10—Coke ovens and by-products plant, relative to high-line bunkers

Works	Coke Ovens Relative to Site ' Entrance '			Coke Ovens Relative to High-Line Bunkers			
	1 Distance, yd.	2 Means of Transport	3 Nature of Route	4 Distance, yd.	5 Quadrant (Fig. 10)	6 Means of Transport	7 Nature of Route
A			NO PLANT				
B	450	WAGONS AND CONVEYORS	DIRECT	650	III	CONVEYORS	DIRECT
C	1100	WAGONS AND CONVEYORS	REASONABLY DIRECT	700	II	WAGONS AND CONVEYORS	REASONABLY DIRECT
D	900	WAGONS AND CONVEYORS	DIRECT	(*a*) 250 (*b*) 500	IV IV	CONVEYORS CONVEYORS	DIRECT DIRECT
E			NO PLANT				
F	330	WAGONS AND CONVEYORS	DIRECT	230	IV	CONVEYORS	DIRECT
G	500	WAGONS AND CONVEYORS	DIRECT	450	I	WAGONS	CIRCUITOUS
H			NO PLANT				
J	300 (WHARF) 1300 (RAIL)	WAGONS AND CONVEYORS	MOSTLY DIRECT	120	III AND IV	CONVEYORS	DIRECT
K	800	WAGONS AND CONVEYORS	CIRCUITOUS	70	III AND IV	CONVEYORS	DIRECT
L	1800	WAGONS AND CONVEYORS	DIRECT	400	II AND III	CONVEYORS	DIRECT
M	600	WAGONS AND CONVEYORS	REASONABLY DIRECT	700	IV	TRAMS ON ROPEWAY	CIRCUITOUS
N	1100	WAGONS AND CONVEYORS	MOSTLY DIRECT	300	III AND IV	CONVEYORS	CIRCUITOUS
O			NO PLANT				
P	1600*	WAGONS AND CONVEYORS	CIRCUITOUS*	500	I AND IV	CONVEYORS	DIRECT
Q	400*		CIRCUITOUS*	300	IV	CONVEYORS	DIRECT

* Actual distance is about three times this value

ments. It is important that this distance should be sufficient to accommodate the raking girders carrying the skip hoist at a satisfactory angle, together with the skip pit for the twin (or balanced) skip hoists, which method is now widely accepted as the most efficient.

In the existing works visited, except for works *L*, the high-line bunkers are immediately in front of the blast-furnaces, which are fed mostly by inclined skip hoists. At works *J* the high-line bunkers are about 80 yards from the centre-line of the blast-furnaces, which are fed by Pohlig cylindrical and conical skips. This arrangement has the disadvantage that locomotives have to be kept in commission solely for transferring the loaded and unloaded skips on bogies between the high-line bunkers and the skip hoists. As a scheme, therefore, from the point of view of layout, it is not desirable.

Ore Treatment

The capacity, arrangement, and location of the ore-treatment plant is an important and highly intricate component of ore-reception layout referred to at the beginning of this section, and must therefore receive further consideration before any specific recommendation can be offered. In the meantime the whole process of ore treatment is being investigated and developed in this country and some accounts of this have already been published.[3]

So far as the present authors' remarks are concerned, these are confined to crushing, screening, drying, and sintering (or agglomerating or briquetting). The provision of plant for ore beneficiation or ore roasting and for bedding or blending is regarded as an extension to the main problem of the layout of the principal units of an integrated iron and steel works.

Where ore is shipped to the site, provision should be made for a direct route *via* the grabbing-trough to the stockyard. With this arrangement the ore-treatment plant can be accommodated only at either end of the stockyard (*see* Fig. 9). If situated on the ' front ' side of the blast-furnaces, the ore would have to double ' back ' past the blast-furnaces, and this seems open to objection.

Where ore is conveyed to the site by rail, the ore-treatment plant might reasonably be situated nearest the holding-sidings, whether these adjoin the stockyard (as in Figs. 9*c* and 9*d*) or whether they are on the ' front ' side of the blast-furnaces.

The situation of the ore-treatment plant must enable the ore to be crushed, screened, and sintered, either before it is placed in the stockyard or prior to its deposition in the high-line bunkers. This is practicable in the four layouts illustrated in Fig. 9. Where the ore-treatment plant is situated at one end of the stockyard, the possibility of extension of the high-line bunkers and stockyard must of necessity be confined to the other end. Such extension cannot be continued indefinitely, and if still larger capacity is required then the plant unit as a whole must be repeated.

Blast-Furnace Plant

Blast-furnaces should preferably be arranged in line, and for efficient operation should be grouped in units. There is little evidence to determine the best size and number in each group, but the latter is believed to be four.[4] For the reasons given in the earlier section on " High-Line Bunkers," furnaces should be parallel to the high-line bunkers and fed by balanced skips on inclined hoists.

Tracks should preferably be arranged parallel to the centre-line of, and at each side of, the blast-furnaces. The tracks between the blast-furnaces and the high-line bunkers should preferably be slag roads, and those on the far side for hot metal and flue dust. The number of cross-overs can be varied to suit the varying quantities of hot metal and slag to be conveyed. Where a high proportion of slag is produced, as is the case from home ores, it may be necessary to allocate tracks on both sides of the furnaces to slag ladles, whilst the hot-metal ladles are accommodated on cross-over tracks passing under and through the cast house.[5]

The earlier arrangement of tracks curving towards the blast-furnaces and terminating in dead-ends is not considered as flexible and satisfactory as the arrangement already described, where tracks run on each side of, and parallel to, the centre-line of the blast-furnaces.

For modern blast-furnaces, stoves and cast houses should preferably alternate in line, with one cast house to two blast-furnaces. The plant required in the cast house can thereby jointly serve two blast-furnaces with resultant economy. With two separate cast houses, this plant would have to be duplicated. Thus, for four blast-furnaces, the sequence should be : Stoves, blast-furnace, cast house, blast-furnace, stoves (for two furnaces), blast-furnace, cast house, blast-furnace, stoves, as is shown in Figs. 9 and 17.

For higher outputs of hot metal with home ores it may be necessary to run cross-over tracks through the cast houses to accommodate more hot-metal ladles and to allow more room for slag ladles on the parallel tracks, as described for dealing with a very high proportion of slag. If the output of the blast-furnaces is still higher, consideration may have to be given to a rearrangement of the cast houses.

To lessen the length of crude gas mains, self-contained gas-cleaning plants, situated beyond the rail tracks, should serve each pair of blast-furnaces. A ' flying ' crude-gas main should carry the crude blast-furnace gas to the primary dust catchers forming part of each gas-cleaning plant on the ' far ' side of the rail tracks. Flue-dust disposal tracks are thereby kept clear of hot-metal and slag roads.

The number of tracks on each side of the blast-furnaces should enable :

(*a*) Hot-metal and slag ladles to be moved independently at each furnace without interfering with the traffic at any other blast-furnace.

(*b*) Flue dust to be removed.

(*c*) New or waste materials to be received or dispatched.

(*d*) Hot metal and slag to be dispatched on separate roads.

It is impracticable to recommend one arrangement of blowing equipment and gas-cleaning plant to suit all conditions. For example, the arrangement of

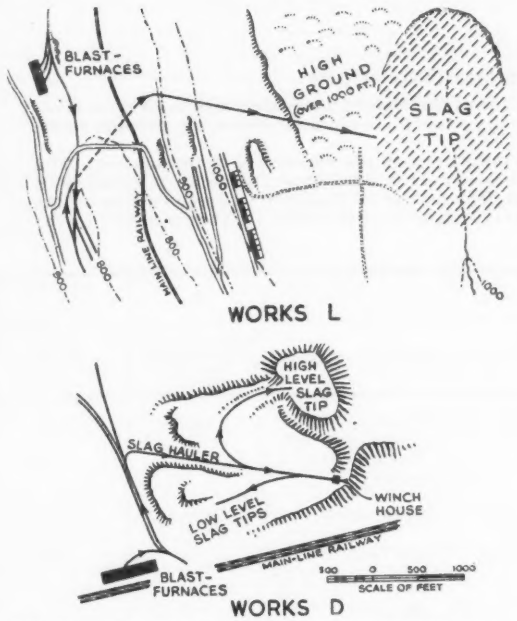


Fig. 11—Disposal of blast-furnace slag at high level

gas-cleaning plant at one end of the line of blast-furnaces, and the blowing-engine house at the other, is upheld by some authorities. Others claim that there is more advantage to be derived from the blowing-engine house being central with the group of blast-furnaces (and situated on the opposite side of the blast-furnaces to that of the high-line bunkers), with separate gas-cleaning plants for each pair of blast-furnaces.

Instrument and control rooms should be arranged as centrally as possible. Lifts, in addition to stair or ladder access to the furnace top, are invaluable.

Hot-Metal Disposal

The route of the hot metal between blast-furnaces and the mixer should be short for economy, but the adoption of 125-ton mixer-type ladles enables hot metal to be transported over long distances without undesirable cooling. The route of the hot metal should be uninterrupted by other traffic.

A pig-casting machine with double strands should be situated near the hot-metal route away from the blast-furnace plant and near the melting shops, so that hot metal may be diverted either to the melting shops or to the pig-casting machine, as demanded by production requirements. One pig-casting machine to two groups of blast-furnaces should be adequate. Pig beds are obsolete, but it would be prudent to have some that can be used in the event of a machine breaking down.

Disposal of Slag, Works Rubbish, and Ash

The problem of the economic disposal of blast-furnace and melting-shop slag, works rubbish, and ash, can be dealt with only when local conditions are known. The first consideration is to put as much slag as possible to a useful purpose by sale to other companies for its re-use, by treatment within the works for use as aggregate for road or building construction, for use as cement, for the making of bricks, or for the manufacture of slag wool for insulation. The only other broad direct use would appear to be the re-claiming and levelling of works sites. After satisfying local demands the remainder can only be dumped, on the ground or at sea, as inexpensively and, if on land, as unobtrusively as possible.

In regard to immediate costs, the tipping of high banks (works *D*, Fig. 11) may be cheaper than the additional freight charge necessary to tip at lower levels over a wider area, but the authors feel that this practice is open to objection, particularly if the bank is within the works boundaries, and is likely to prevent extension in the future. Criticism has also been raised that rail tracks and locomotives are not suited to the severe treatment caused by this method of molten-slag disposal.[2] Another example of tipping at high level is at works *L*, Fig. 11, which is noticeable for the height to which the slag is raised, presumably at some considerable expense. The method of running slag into pits adjacent the blast-furnaces and recovering by digger when solid, is apparently used in several modern plants in the United States of America, but it is considered a nuisance owing to the resulting lack of cleanliness within the precincts of the plant.[6] Where the slag is in demand as road metal it is found to be in better condition for this purpose if allowed to solidify in the ladles ; more ladles are required, but the strain on the locomotives when tipping molten slag, is avoided.

Evidence so far obtained is not conclusive in favour of any particular system, and in view of the considerable cost of slag handling in the industry, this subject is considered to warrant further investigation.

STEELMAKING PLANT

Introduction

The layout of steelmaking plant involves many factors, which include the following :

(1) Type of process, *viz.*, open-hearth or Bessemer.
(2) Proportion of hot-metal and cold-metal charge.
(3) Source of the scrap, *viz.* (*a*) mill scrap and scale, or (*b*) bought scrap.
(4) Nature of the scrap : (*a*) heavy, or (*b*) light, and the proportion of each.
(5) Method of loading the pans : (*a*) in an outside, separate yard and pushed up a ramp to stage level ; (*b*) in an adjoining bay by overhead travelling magnet cranes to pans in cradles at ground level, and thence in cradles lifted on to the stage ; or (*c*) in an adjoining bay by magnet cranes to pans at stage level.
(6) Type of chargers, *viz.*, 'ground slewing,' 'overhead slewing,' or 'fixed ground.'
(7) Method or fuel used for firing mixers and furnaces.
(8) Type of open-hearth furnaces, *viz.*, fixed or tilting.
(9) Method of casting, *viz.*, pit or car.
(10) Method of teeming, *viz.*, from stand or from crane.

It is not practicable at this stage to make detailed recommendations concerning the layout of steelmaking plant, pending the results of research investigations on "Furnace Charging," "Casting and Ingot Handling," and "Melting-Shop Design." This is important because any opinions expressed in this

Table X

BLAST-FURNACES AND MELTING SHOPS

Column 1 gives the relative dispositions (*i.e.*, the angle between the long axes) of the two units ; this gives an indication as to whether an overall plan was originally adopted. Column 2 shows the distance apart (in yards) of the units.

Consideration of the table indicates whether the two units are well placed relative to one another. The ratio of the length of route to the net distance apart is a measure of the directness of the route (*see* column 7).

Column 6 gives the sum of the angles turned through (irrespective of direction) ; a large total indicates a tortuous route. The relative positions of the units and the routes between them are shown clearly on the material flow diagrams, Figs. 18 to 22.

Works	1	2	3	4	5	6	7
	Relative Directions	Distance (Net on Plan), yd.	Length of Route, yd.	Nature of Route	Segregation of Route	Sum of Angles Turned Through (approx.)	Ratio Col. 3/Col. 2
A	5°	130	1310	INDIRECT	TRAVERSES BRIT. RLYS. LINE BETWEEN I. AND S. WORKS	140°	10·0
B	75°	820	1800	CIRCUITOUS	SEGREGATED	512°	2·2
C	8°	350	1000	CIRCUITOUS	TRAVERSES OTHER MAIN ROUTES AND 'BOTTLE-NECK'	170°	2·85
D	43° 54° 87° 82°	530 800 420 500	1220 1320 1450 1120	CIRCUITOUS	NOT SEGREGATED	175° 399° 189° 339°	2·30 1·65 3·45 2·24
E	160°	800	1800	CIRCUITOUS	TRAVERSES ROUTES OF OTHER MATERIALS	275°	2·25
F	0°	280	900	SOMEWHAT CIRCUITOUS	CROSSES ONE MAIN ROUTE	103°	3·2
G	0°	130	600	SOMEWHAT CIRCUITOUS	TRAVERSES ROUTES OF OTHER MATERIALS	200°	4·6
H	118°	1400	1600	DIRECT	TRAVERSES ROUTES OF OTHER MATERIALS	320°	1·15
J	30°	330	330	DIRECT	SEGREGATED	60°	1·0
K	0°	330	330	DIRECT	SEGREGATED	30°	1·0
L	0°	300	1400	CIRCUITOUS	TRAVERSES ROUTES OF OTHER MATERIALS	285°	4·7
M	68°	330	1100	SOMEWHAT CIRCUITOUS	SEGREGATED	194°	3·45
N	20°	600	1400	CIRCUITOUS	TRAVERSES OTHER MAIN ROUTES AND 'BOTTLE-NECK'	337°	2·35
O	...	...	...	...	...	...	...
P	0° 44° 23° 14° 30° 37°	280 1300 1900 800 800 1500	900 2300 3300 1100 1800 2200	CIRCUITOUS	TRAVERSES ROUTES OF OTHER MATERIALS	201° 405° 522° 293° 379° 358°	3·2 1·75 1·75 1·4 2·25 1·45
Q	62°	200	800 or 900	CIRCUITOUS	TRAVERSES ROUTES OF OTHER MATERIALS	202° or 214°	4·0 or 4·5

paper may require to be qualified or modified when the results of the investigations on these subjects have been reached. Remarks on steelmaking plant in this paper are therefore confined to a broad survey of the essential requirements when forming one unit of an integrated steelworks.

Materials Reception—Steelplant Sidings

Steelplant sidings should conform to the following conditions :

(1) They should be separate from the main incoming exchange sidings, be close to and convenient to the melting shop, and be large enough for the satisfactory handling of the large variety of materials required in a melting shop.

(2) They should be arranged so that locomotives can withdraw wagons and push them into the melting shop and so that the locomotives do not have to change ends of a rake of wagons to avoid being 'locked-in' themselves after entering the melting shop.

(3) There should be access from the sidings to the melting shop which must be achieved with the minimum amount of shunting. The precise optimum arrangement of steelplant sidings relative to the melting shop must form the subject of a later and more detailed quantitative analysis, described in the conclusions of this paper. The access from the sidings to the melting shop must not necessitate passage over main works 'running' lines.

(5) There should be loops at both ends of the sidings to facilitate the extraction of the particular wagons required at any time by the production process.

(6) Tracks should be level so that the access to the melting shop is level ; an up-grade, as occurs at certain existing works, is not desirable.

Scrap Stockyard

Under this heading, a scrap stockyard having a reserve capacity and entirely *separate* from the melting-shop building is implied. Such a stockyard is usually necessary, as a 'buffer' storage for purchased scrap. Where 'circulation' scrap only is used, pans filled with circulation scrap are preferably taken directly to the charge holding bay (in a stage loading system) or to the loading bay (in a bench system).

Requirements for a separate scrap stockyard are as follows :

(1) It should be large enough to segregate the various types of scrap.

(2) It should be close and convenient to the melting shop and the steelplant sidings.

(3) There should be direct access from the scrap stockyard, requiring the minimum amount of shunting, to either : (*a*) The charge loading bay in the melting shop, or (*b*) separate box (or pan) loading-sidings (where boxes or pans can be loaded from railway wagons).

(4) The rail tracks giving access to the scrap stockyard should either run through, and have adequate turn-outs for inserting or extracting rakes of wagons, or they should be arranged so that locomotives are always on the correct ends of rakes of wagons or box (or pan) bogies.

(5) It should preferably not be covered.

As mentioned in the introduction to this paper, it is not practicable, in view of its scope, to go into a quantitative analysis of storage capacity in relation to ingot output. The precise capacity, arrangement, and position of the scrap stockyard, and the determination as to whether a scrap stockyard is required in any specific instance, is the subject of a separate research now being carried out.

Melting Shops—Accommodation

The accommodation to be provided in the melting shop will vary with the factors enumerated in the introduction to the section on "Steelmaking Plant." An indication is given below of the accommodation which the authors have in mind and which may, wholly or in part, have to be provided :

Raw-materials bay	Pan-mill section (dust-proof covered)
Scrap-box filling (or stock-yard) bay	Refractories storage
Charge holding bay	Maintenance stores
Furnace bay	Maintenance workshop
Casting bay	Offices
Ladle-repair bay	Laboratory
Mould-preparation bay	Cabins
Fuel-plant bay	Control rooms

Some of the foregoing items may not be separate bays but may be included in one of the other bays referred to. The exact overall arrangement is dependent upon both the layout of the plant and the nature of the movement of material inside the shop. This is the subject of concurrent research and will not be discussed here.

One important factor in determining the arrangement of melting shops is the elimination, where possible, of railways for transferring scrap bogies, owing to the constant risk of derailment caused by falling scrap.

Location of Melting Shops Relative to Blast-Furnaces

The distance between the mixer in the melting shop and the blast-furnaces should be such that the route for the hot metal is reasonably short and is uninterrupted by other traffic, as already noted under "Hot-Metal Disposal." Where, in accordance with current practice, railways are used, schemes 1·0*a*, 1·1*a*, 1·5*a*, 2·1*a*, 2·2*a*, 2·5*a*, and 2·6*a* (*see* Figs. 16 and 17) have the advantages and disadvantages discussed in the section on "Comparative Analysis of Layouts." Where railways employing the usual steam-locomotive-drawn rolling stock can be dispensed with in favour of electric transfer cars, conveyors, or other mechanical means, scheme 3 (Figs. 16 and 17) has considerable advantages because the hot metal can be delivered directly to the centre of the melting shop.

Arrangements in existing British works are given in Table X.

Disposal of Melting-Shop Slag

Where the process is basic, molten melting-shop slag should be transported to pits into which the slag ladles are drained. This systematizes the process instead of having haphazard bank tipping. After having first been sprayed the slag should be reclaimed by mechanical shovel and thereafter transported to a basic slag works for crushing and grinding. Only where the slag can be fully reclaimed, should the pits be located within the confines of the area occupied by the plant. It is also common practice to run open-hearth slag into a pit below the furnace for subsequent removal by an overhead travelling crane, but this method does not allow the shop to be cleared rapidly.

Table XI

STRIPPING AND SOAKING-PIT BAYS

This table shows the variety of layouts which exists. ' Skew arrangements,' as at works *C* and *F*, are not recommended, nor are those which involve sharp rail bends, as at works *E* and *Q*. Straight formations, as at works *L*, *M*, *N*, and *O*, are considered preferable. The arrangements described under this table are illustrated in Fig. 12.

Works	Type of Casting Practice	Stripping Bay Relative to Melting Shop			Soaking Pits Relative to Stripping Bay			Mills Relative to Soaking Pits
		Separate	Adjoining	Distance (approx.), yd.	Separate	Adjoining	Distance (approx.), yd.	All Adjoining
A	PIT	...	IN CASTING BAY	...	...	DIRECTLY AND PARALLEL TO CASTING BAY	30	IN LINE WITH
B	PIT	...	IN CASTING BAY	...	...	DIRECTLY WITH 'T' FORMATION	...	DIRECTLY WITH 'L' FORMATION
C	CAR	AT 'SKEW' ANGLE	...	600 1300	...	DIRECTLY 'END-ON'	...	DIRECTLY WITH 'L' FORMATION
D	CAR	...	EXTENSION TO EXISTING BAY	...	...	DIRECTLY WITH 'T' FORMATION	NIL AND 530	OVER LENGTH OF PITS
E	CAR	...	AT END OF CASTING BAY	...	AT RIGHT-ANGLES TO STRIPPING BAY	...	300	OVER LENGTH OF PITS
F	CAR	AT 'SKEW' ANGLE	...	200	AT 'SKEW' ANGLE	...	250	IN LINE WITH SOAKING PITS
G	CAR AND PIT	STRIPPING CARRIED OUT AT ADJACENT WORKS						
H	PIT AND TRANSFER CAR	...	AT END OF CASTING BAY	...	...	DIRECTLY AND IN LINE WITH STRIPPING BAY	...	DIRECTLY WITH 'T' FORMATION
J	CAR AND PIT	...	BOTH IN AND ADJOINING CASTING BAY	...	...	DIRECTLY WITH 'T' FORMATION	...	OVER LENGTH OF PITS
K	CAR	AT ONE SIDE	...	500	...	'CROSS' FORMATION	...	'L' FORMATION
L	CAR	AT SOME DISTANCE	...	2300	...	DIRECTLY AND IN LINE WITH STRIPPING BAY	...	AT END OF SOAKING PITS
M	CAR	PARALLEL TO MELTING SHOP	...	600	...	DIRECTLY AND IN LINE WITH STRIPPING BAY	...	AT END OF SOAKING PITS
N	CAR AND PIT	AT 'SKEW' ANGLE	...	450	...	DIRECTLY AND IN LINE WITH STRIPPING BAY	...	DIRECTLY AT END OF SOAKING PITS
O	PIT AND TRANSFER CAR	...	IN CASTING BAY	...	...	DIRECTLY AND IN LINE WITH STRIPPING BAY	...	DIRECTLY AT END OF SOAKING PITS
P	CAR	ENTIRELY SEPARATE FROM MELTING SHOPS	...	600 2200 1600 1070	...	DIRECTLY WITH 'T' FORMATION	...	OVER LENGTH OF PITS
Q	CAR	...	IN LINE WITH CASTING BAY	...	AT RIGHT-ANGLES TO STRIPPING BAY	...	350	DIRECTLY IN LINE WITH SOAKING PITS

The route for the slag ladles should be as short as possible and should involve the minimum amount of shunting. In addition to rail access, satisfactory road access should be provided to the basic slag plant for the removal of the finished products.

Where the acid process is used, the slag will be of no use for the purpose described above. Disposal in this case should follow the lines already suggested for blast-furnace slag. This subject of the disposal of open-hearth slag, as mentioned in the section on the disposal of blast-furnace slag, merits further consideration.

Fig. 12—Stripping and soaking-pit bays

ROLLING MILLS

Influence of Finished Product on Layout

In view of the diversity of the nature of the finished product it is not proposed in this paper to examine the detailed arrangements of rolling mills. There are, however, certain observations which should be made about the principal features of mills, and these are mentioned in the succeeding sub-sections.

The arrangement of the mill buildings is influenced to a large extent by the nature of the finished product, which can be divided broadly into three groups, namely, plate, section (and rod), and tube. Another factor is whether the mills are continuous or not. The size or capacity of the mill requires to be taken into consideration, as, for example, plate mills are usually larger than section mills and deal with a greater tonnage, whilst tube mills vary over a wide range of production.

Stripping and Soaking-Pit Bays

The stripping, soaking-pit, and mould-preparation bays should be so arranged as to ensure complete flexibility between all three operations. In this paper, the term ' soaking pit ' is used to cover fired reheating furnaces ; chambers not fired are referred to as ' dead soaking pits.'

Soaking pits should be reasonably close to the stripping bay to conserve heat in the ingots, whilst the desired flexibility may be attained by locating the three operations in separate buildings. On the other hand, with the possible sacrifice of some flexibility, the arrangement of these operations in one building would enable the flow of ingots to be sustained in the event of a derailment, by the use of electric overhead travelling cranes.

The authors are inclined to favour the stripping and soaking pits in line, forming virtually part of the mill building, and not laid out separately at skew angles, as in many examples in Fig. 12.

As ingots are so liable to fall on the floor it is preferable to avoid the use of junctions and cross-overs within the bays.

Preheaters, in addition to soaking pits, will be necessary for heating the cold ingots from stock. ' Dead ' soakers have applications in some works, but in others they have been found to be unnecessary and their use has been discontinued.

Where railways and steam locomotives are used, schemes $1 \cdot 0a$, $1 \cdot 1a$, $1 \cdot 5a$, $2 \cdot 1a$, $2 \cdot 2a$, $2 \cdot 5a$, and $2 \cdot 6a$ (Figs. 16 and 17) have the advantages and disadvantages discussed in the section on " Comparative Analysis of Layouts." Where transfer cars or other forms of mechanical handling can be used in lieu of the usual method of car casting, the arrangement in which the stripping bay and soaking pits lead directly off the casting bay, as in scheme $3 \cdot 0$, has considerable advantages. The arrangements in existing works are described in Table XI.

Ingot Storage

Storage of some ingots can usefully be arranged in the soaking-pit bays. Storage of cold ingots should be provided for on the site, but the areas need not be closely defined.

Ingots stored in the soaking-pit bays will be dealt with by the ingot-handling cranes. If the outside storage areas for cold ingots can also be covered by an overhead travelling crane on a gantry it is considered that this would be more efficient than the use of steam cranes. A suggested arrangement is illustrated in Fig. 13.

It is not practicable at this stage to consider a quantitative analysis of storage capacity in relation to ingot output.

Mill Bays

Soaking-pit bays, cogging- or slabbing-mill bays, and roughing- and finishing-mill bays should be arranged to provide a forward flow from ingot to finished product. As a railway system is not employed, there is no reason why the cogging or slabbing mill should not be set at any desired angle to the soaking pits.

The planning of mill bays is affected very much by the extent to which electric overhead travelling cranes can be eliminated. For example, by using this type of crane, it is not practicable to pass material from one bay to another ; planning is more flexible with rollers, skids, transfer cars, etc. Another point to observe in connection with overhead travelling cranes is that the tare weight of the crane, compared with the weight lifted, is high, and in addition the crane has to make a larger number of journeys for a given tonnage than, say, a transfer car or cars, resulting in high wear and tear and high maintenance costs. Further, the capital cost of the crane and gantry is probably greater than for other methods of internal transport. Cranes should therefore be used only for lifting and placing material in one limited area ; they should not be relied upon for transport over any appreciable lengths between the cogging mill and finishing racks, for which rollers, transfer cars, or ' chariots ' are more suitable.

Disposal of Finished Products

In this survey, the authors are particularly concerned with the way in which the tracks emerge from the mill and connect with the works railway system. It is considered, therefore, that the loading tracks should extend longitudinally, *i.e.*, in line with, or parallel to, the general forward flow through the mills from ingot to finished product, thus making

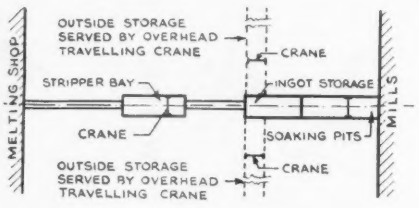


Fig. 13—Ingot storage

Fig. 14—Finishing banks

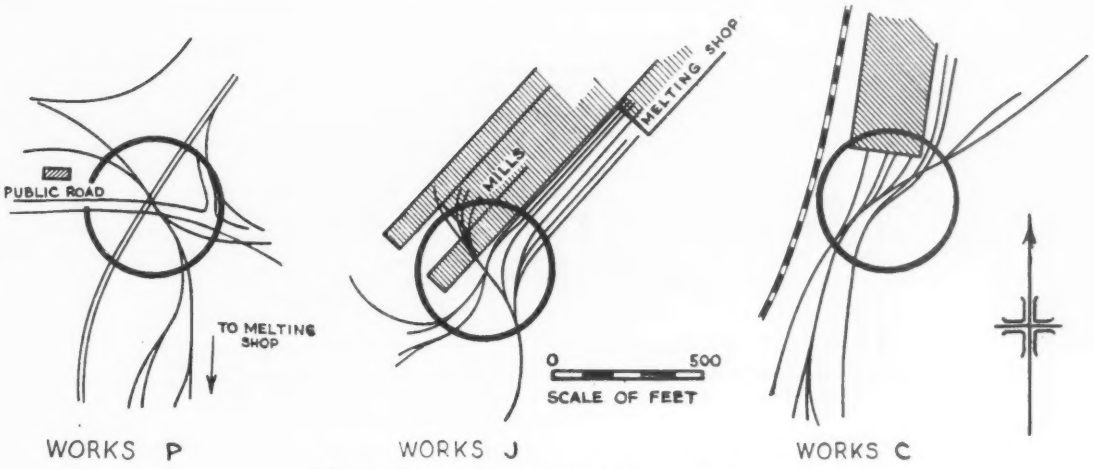


Fig. 15—Main traffic routes—direct crossings

the dispatch of finished product a continuation of this forward flow, as illustrated in Fig. 14. Water access is invaluable if markets are overseas, and in certain British works direct loading to ships is practicable.

The many possible arrangements of loading bays for dispatching products *via* main-line railways are considered to be worth a separate investigation.

INTERNAL TRANSPORT

Although there are a number of forms of transport which can be used in various parts of an iron and steel works, only two, namely, railways and roads, have a predominant effect on the layout. These two only have therefore been considered in this paper.

Railways

Layout—As railways are the principal means of transport within the works, it is, as has already been inferred, the ' pattern ' of the railway system which determines the features of the layout. In other words, the works must be *built round the railway system*, and the relative position of the various unit processes must be subordinated to the limitations of railway transport.

The track layout should conform with the broad principles of materials-handling, *viz.* :

(1) There should be a forward flow of material through the works.

(2) Routes of materials should be well defined, they should not cross one another (as at works *C*, *J*, and *P*—Fig. 15), and they should be as short and as direct as possible and should entail the minimum amount of shunting.

Gravity flow gradients should be arranged where possible to assist the transfer of wagons by hand after they have been placed in position by locomotives or electric haulers, as mentioned in the discussion on rail-borne ore, under " Ironmaking (Blast-Furnace) Plant." Routes for hot metal and hot ingots should be duplicated, or at least there should be alternative routes.

Sidings—Careful consideration should be given to the arrangement of siding connections. In general, sidings with loops at both ends are desirable, but in certain cases dead-end sidings are preferable ; for example, in short scrap sidings it is convenient to be able to draw out the bogies and push them into the shop by a locomotive at one end, and a dead-end will prevent other traffic from encroaching from the further end of the siding.

As mentioned in the introduction to this paper, it is not practicable, in view of its scope, to consider quantitative analyses of siding capacity in relation to the ingot output. However, some guiding principles should be stated :

(1) Siding capacity should be sufficient for the usual works traffic, but space should be available to increase the number of sidings if necessary.

(2) Incoming sidings should, if possible, be large enough to accommodate irregular volumes of incoming materials.

(3) Holding-sidings should be close to their respective departments and should, as far as possible, permit a gravity feed of the wagons to their destination.

(4) Outgoing sidings should be sufficiently large to enable various types of wagon to be selected and marshalled as required by the range of finished products.

Gradients—Except in the case of gravity sidings, rising gradients should be avoided. Where used, rising gradients should be ' compensated ' by arranging that gradients on curves shall be lower than on straights. The effect of this is to enable the tractive effort required by the engine to remain reasonably constant over the whole length of gradient. An example occurs at works *P*, where the alteration of a gradient on the curve has enabled more trucks or wagons to be hauled on each journey.

Turn-Outs and Crossings—Turn-outs should be altered as necessary to suit whatever changes have to be made in traffic arrangements. Diamond crossings should not be arranged so that main-line traffic crosses, and should be avoided on casting-car routes and in casting bays.

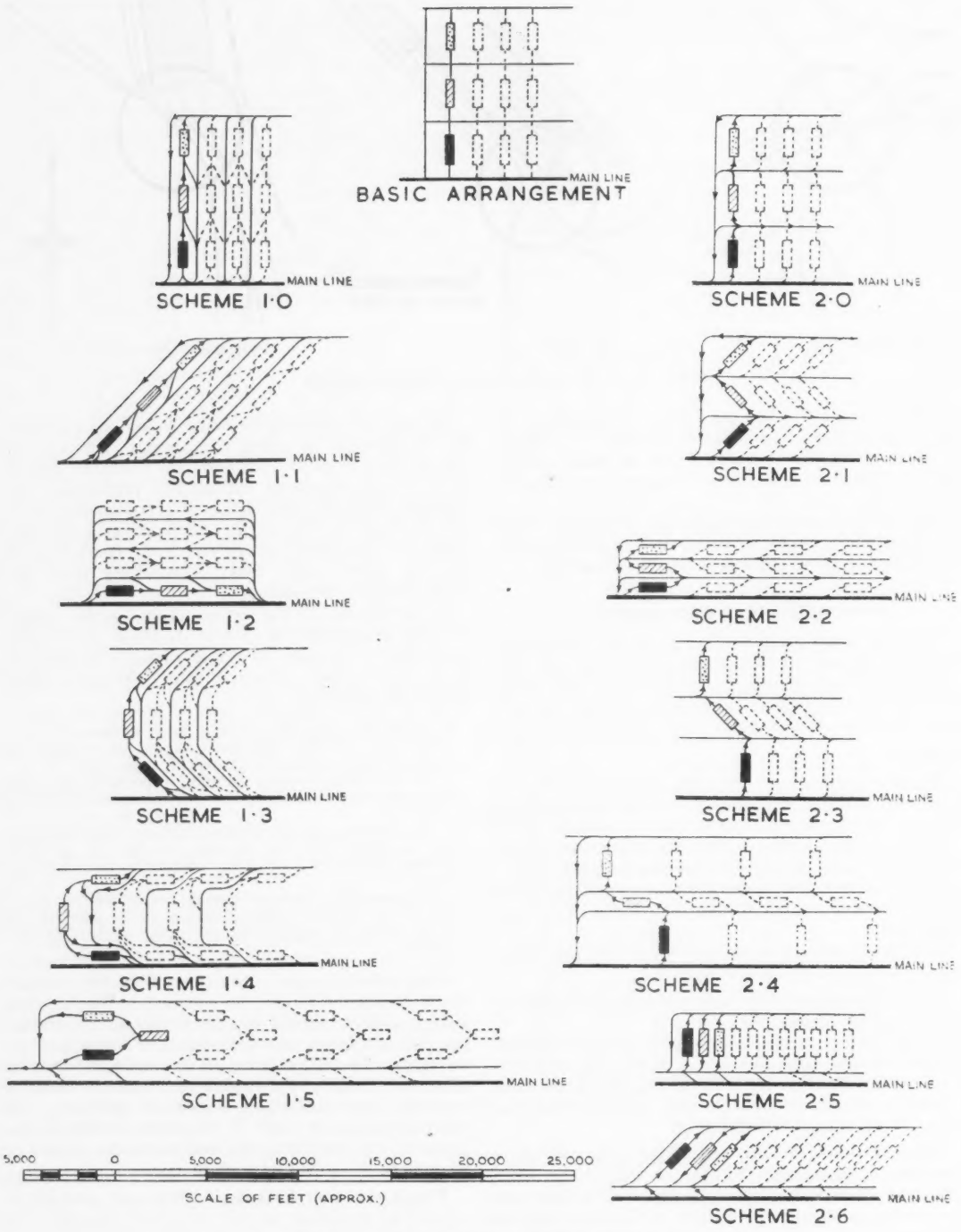


Fig. 16(*a*)—Evolution of possible layouts (block plans)

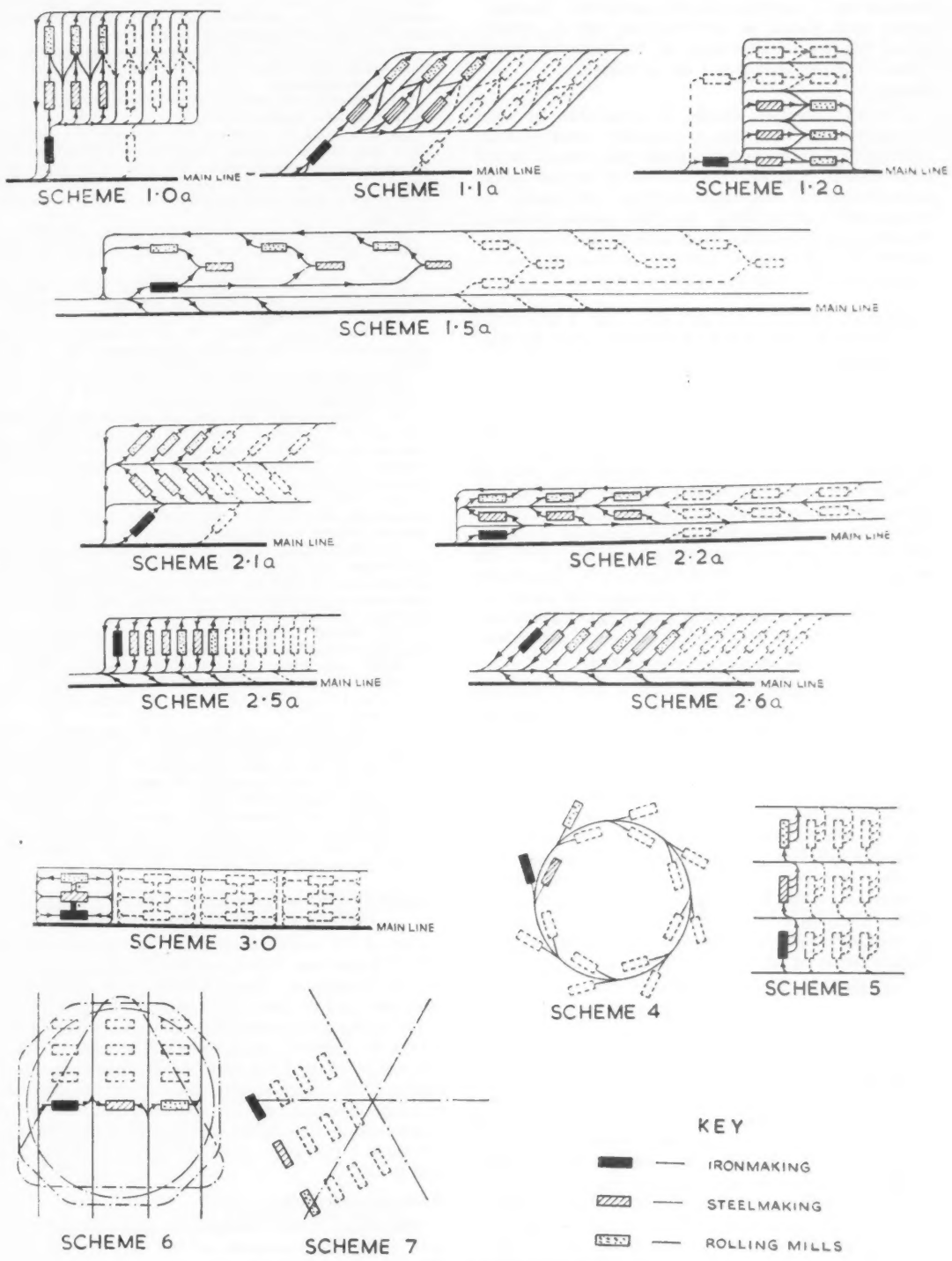
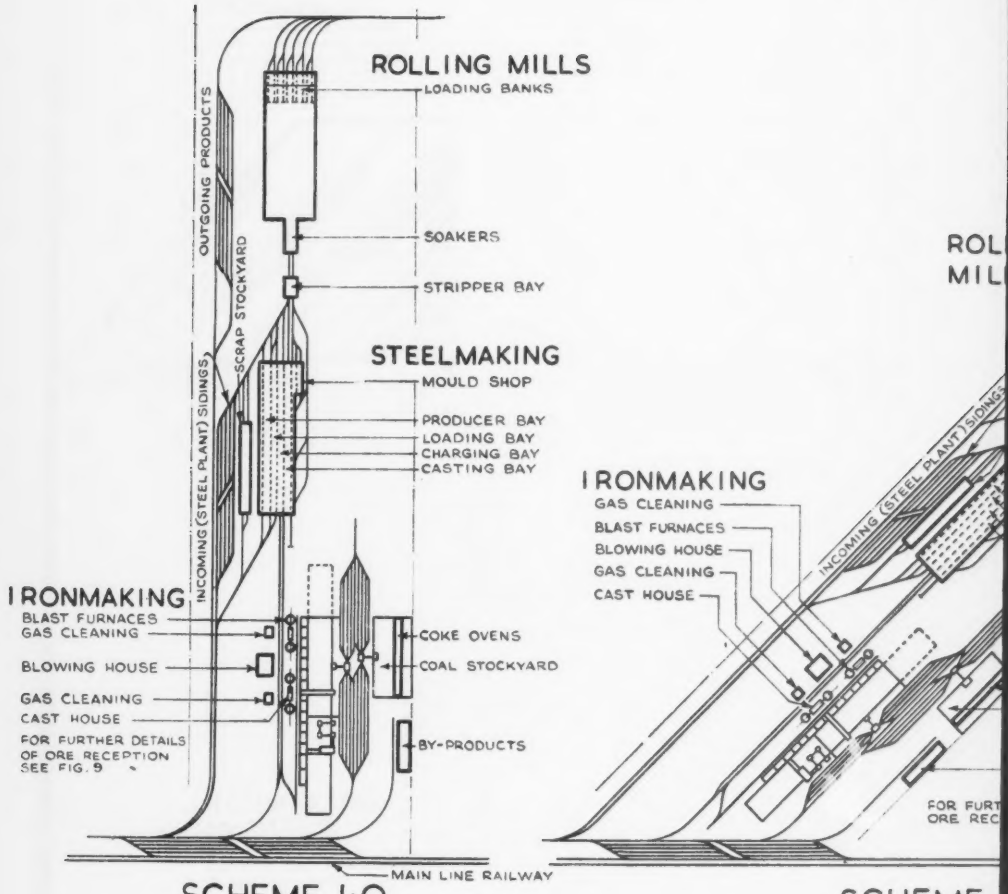


Fig. 16(*b*)—Evolution of possible layouts (block plans)


ROLLING MILLS
LOADING BANKS
SOAKERS
STRIPPER BAY
STEELMAKING
MOULD SHOP
PRODUCER BAY
LOADING BAY
CHARGING BAY
CASTING BAY
IRONMAKING
BLAST FURNACES
GAS CLEANING
BLOWING HOUSE
GAS CLEANING
CAST HOUSE
FOR FURTHER DETAILS OF ORE RECEPTION SEE FIG. 9
COKE OVENS
COAL STOCKYARD
BY-PRODUCTS
OUTGOING PRODUCTS
INCOMING (STEEL PLANT) SIDINGS
SCRAP STOCKYARD
MAIN LINE RAILWAY
SCHEME 1·0
ROL
MIL
IRONMAKING
GAS CLEANING
BLAST FURNACES
BLOWING HOUSE
GAS CLEANING
CAST HOUSE
INCOMING (STEEL PLANT) SIDING
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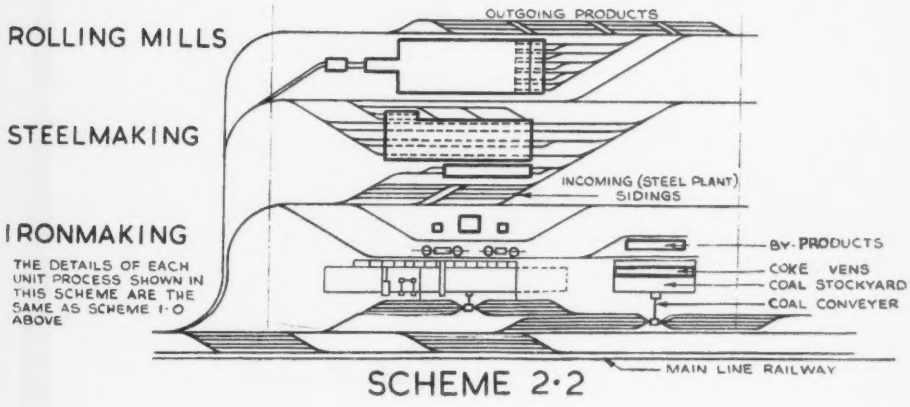

ROLLING MILLS
STEELMAKING
IRONMAKING
THE DETAILS OF EACH UNIT PROCESS SHOWN IN THIS SCHEME ARE THE SAME AS SCHEME 1·0 ABOVE
OUTGOING PRODUCTS
INCOMING (STEEL PLANT) SIDINGS
BY-PRODUCTS
COKE VENS
COAL STOCKYARD
COAL CONVEYER
MAIN LINE RAILWAY
SCHEME 2·2

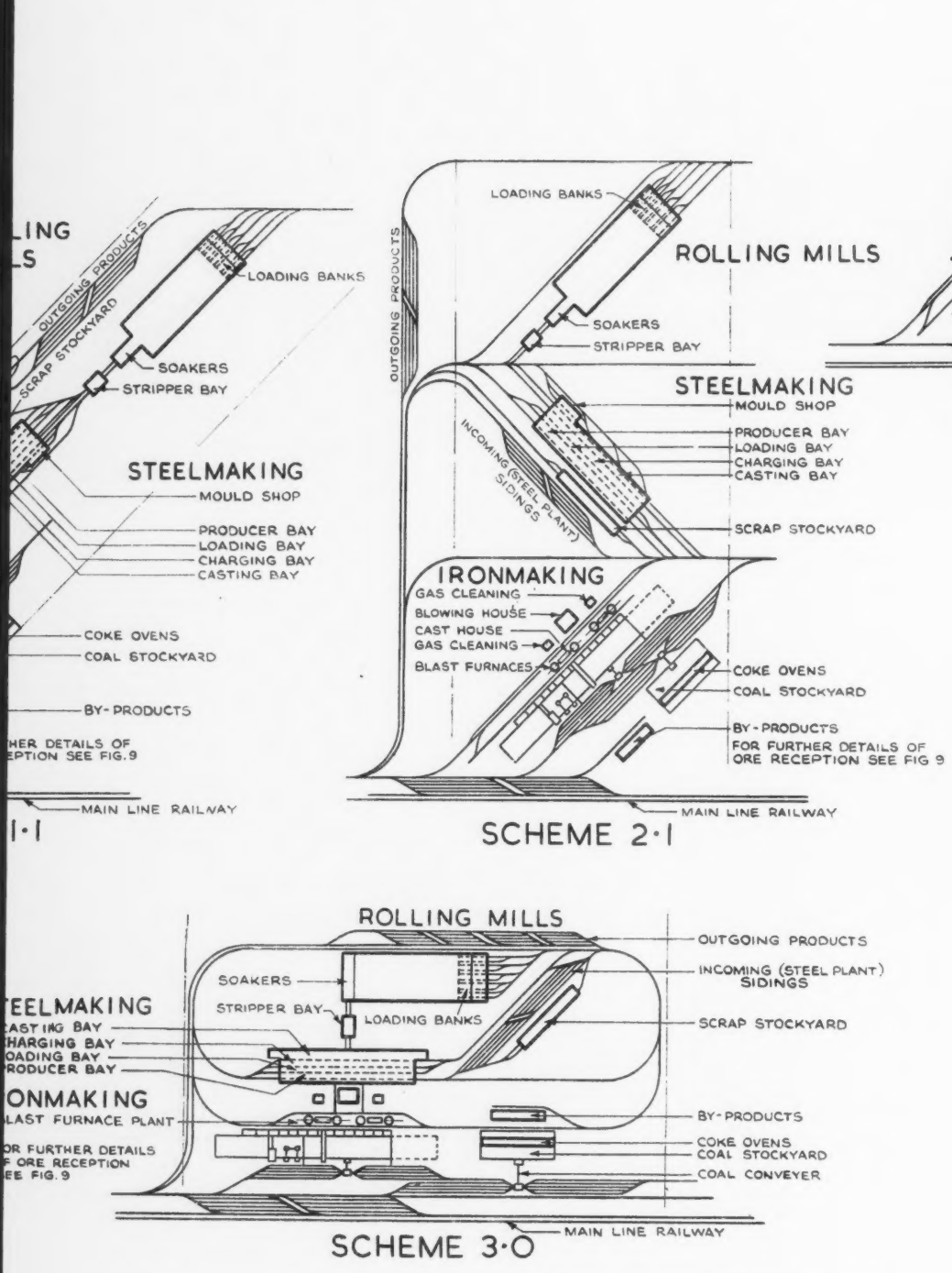
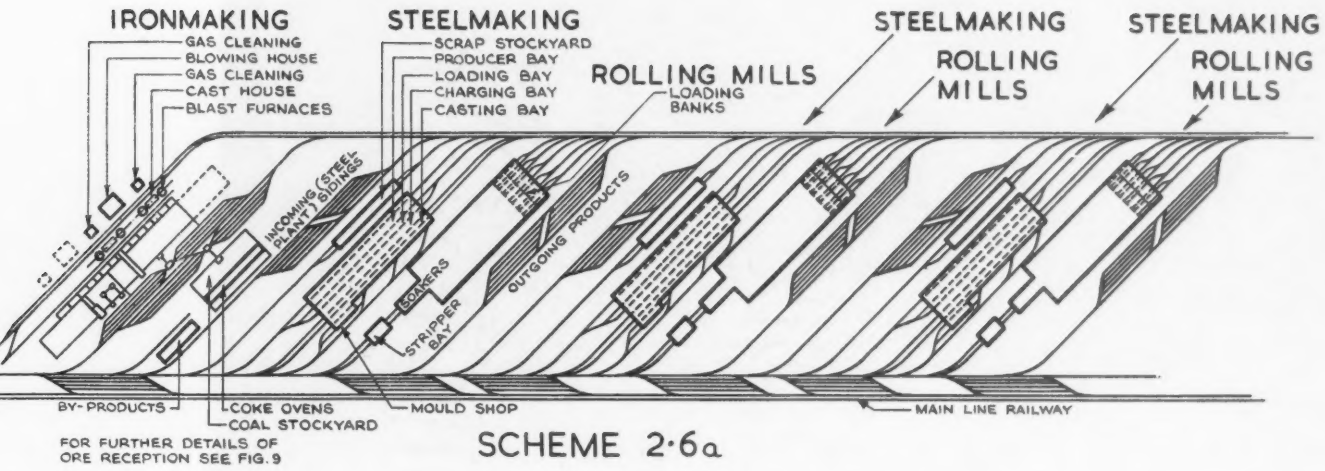
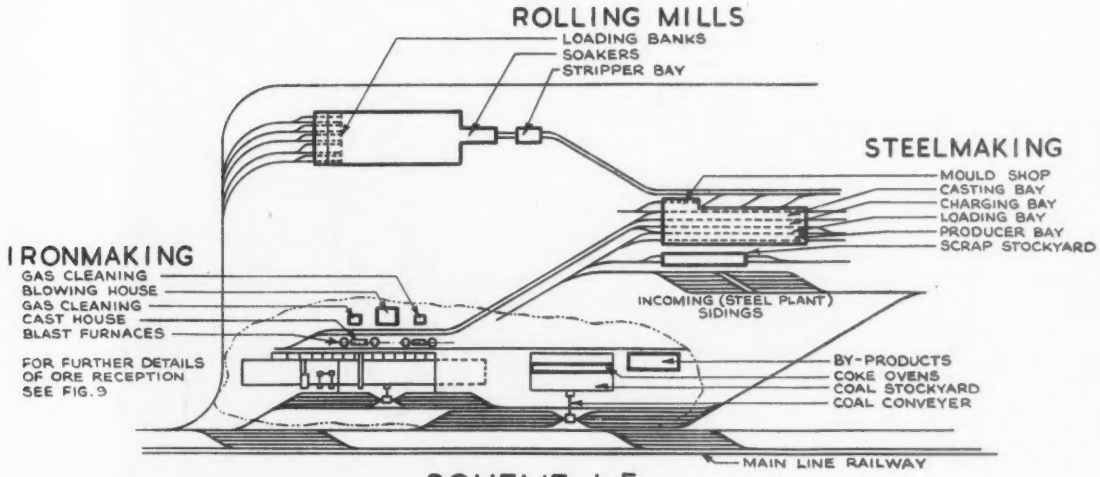


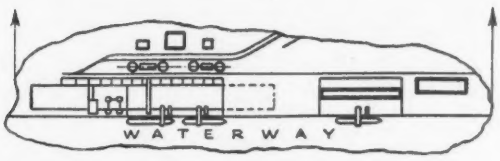
FIG. 17—POSSIBLE DETAILS OF SOME LAYOUTS SHOWN IN FIG. 16

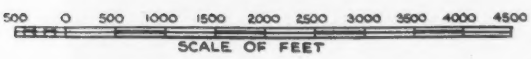


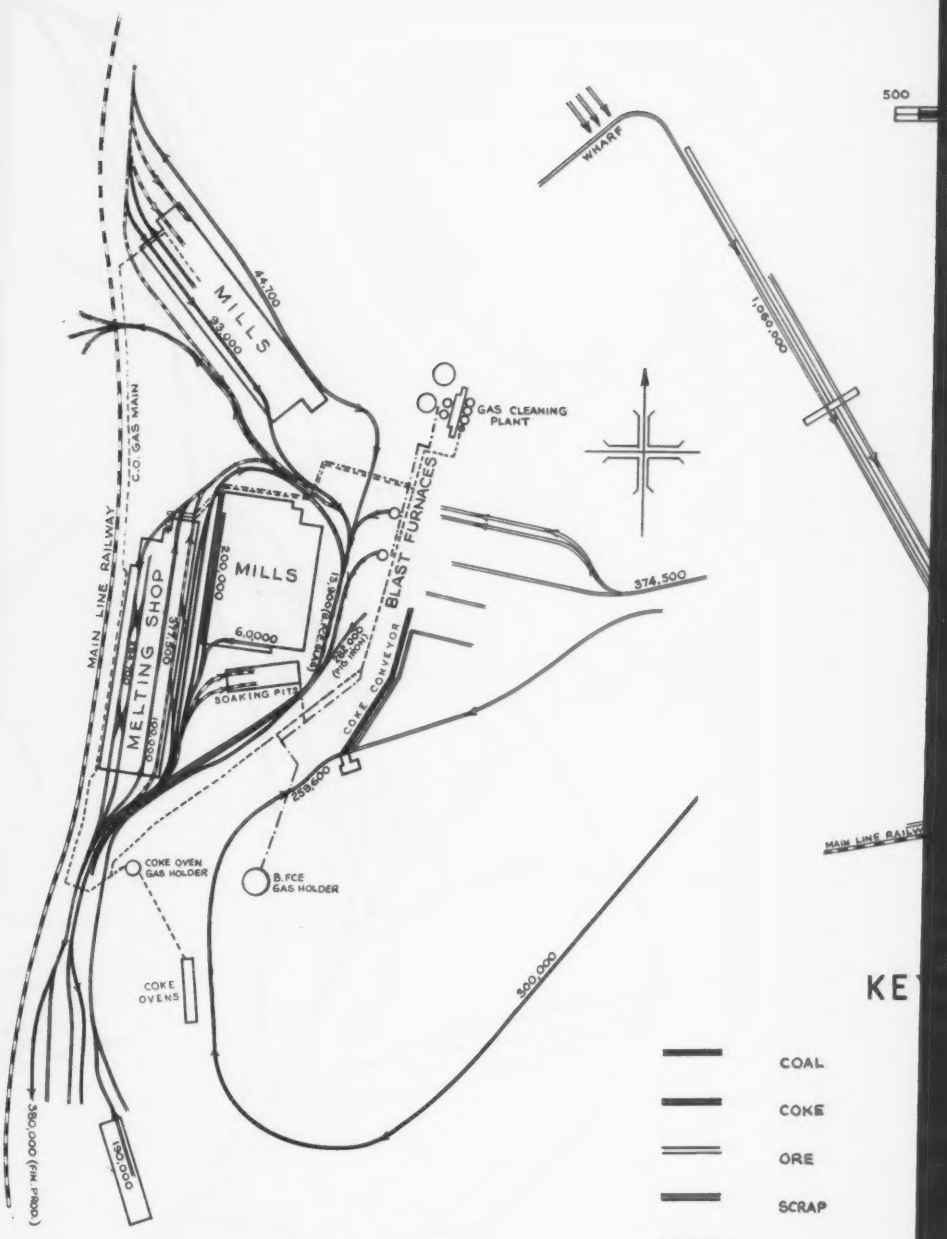
SCHEME 2·6a



SCHEME 1·5a






WHARF
500
1,050,000
MILLS
44,100
33,000
GAS CLEANING PLANT
C.O. GAS MAIN
MAIN LINE RAILWAY
MELTING SHOP
MILLS
600,000
6,0000
SOAKING PITS
BLAST FURNACES
374,500
COKE CONVEYOR
258,600
COKE OVEN GAS HOLDER
B.FCE GAS HOLDER
COKE OVENS
300,000
380,000 (GIN PROD.)
100,000
MAIN LINE RAILWAY
KE
COAL
COKE
ORE
SCRAP
HOT METAL
COLD PIG IRON
NOTE:- WHERE TWO OR MORE MA
THE COLOURS ARE SHOWN
APPROXIMATE ANNUAL Q
THE ROUTE TRAVERSED

WORKS C

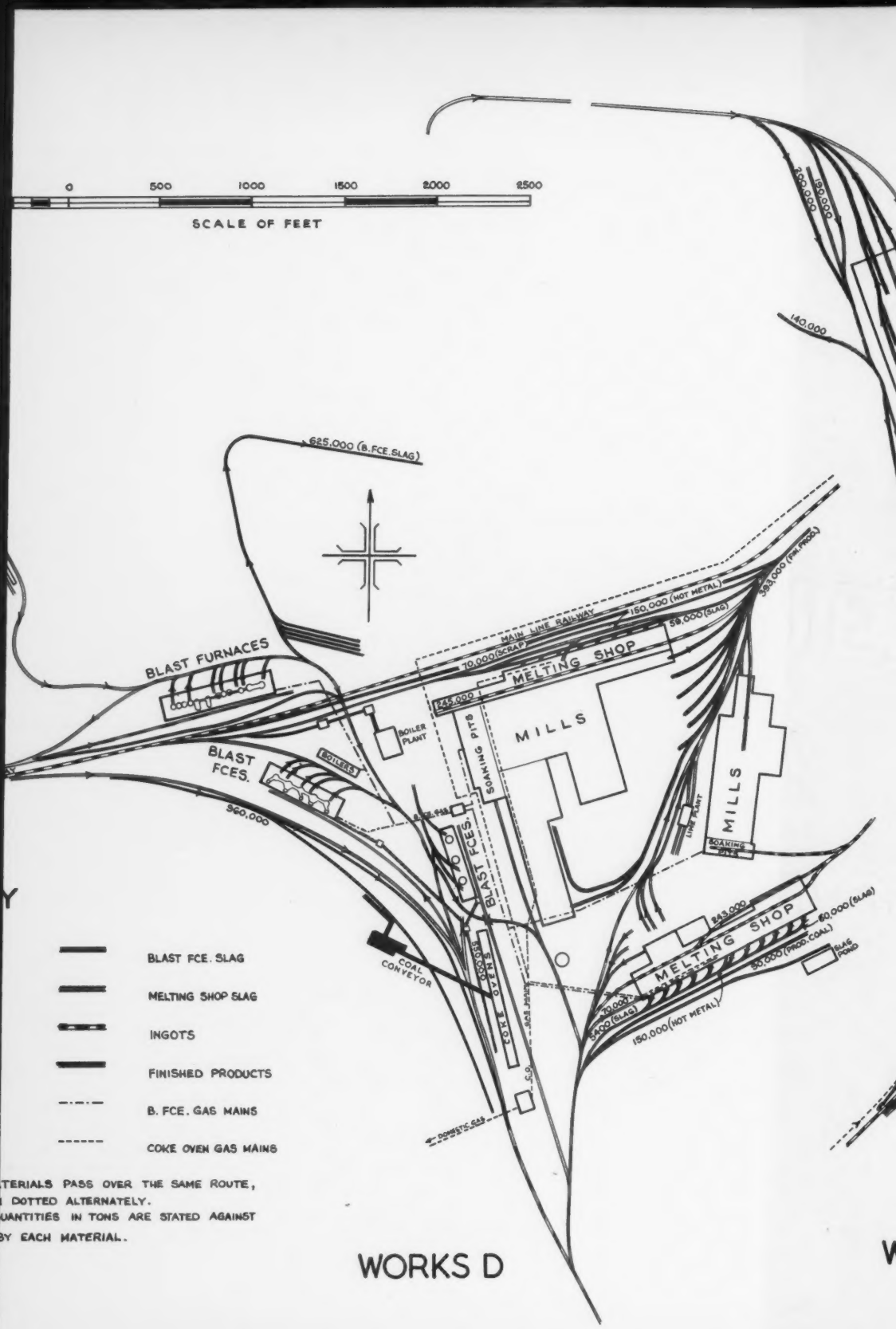
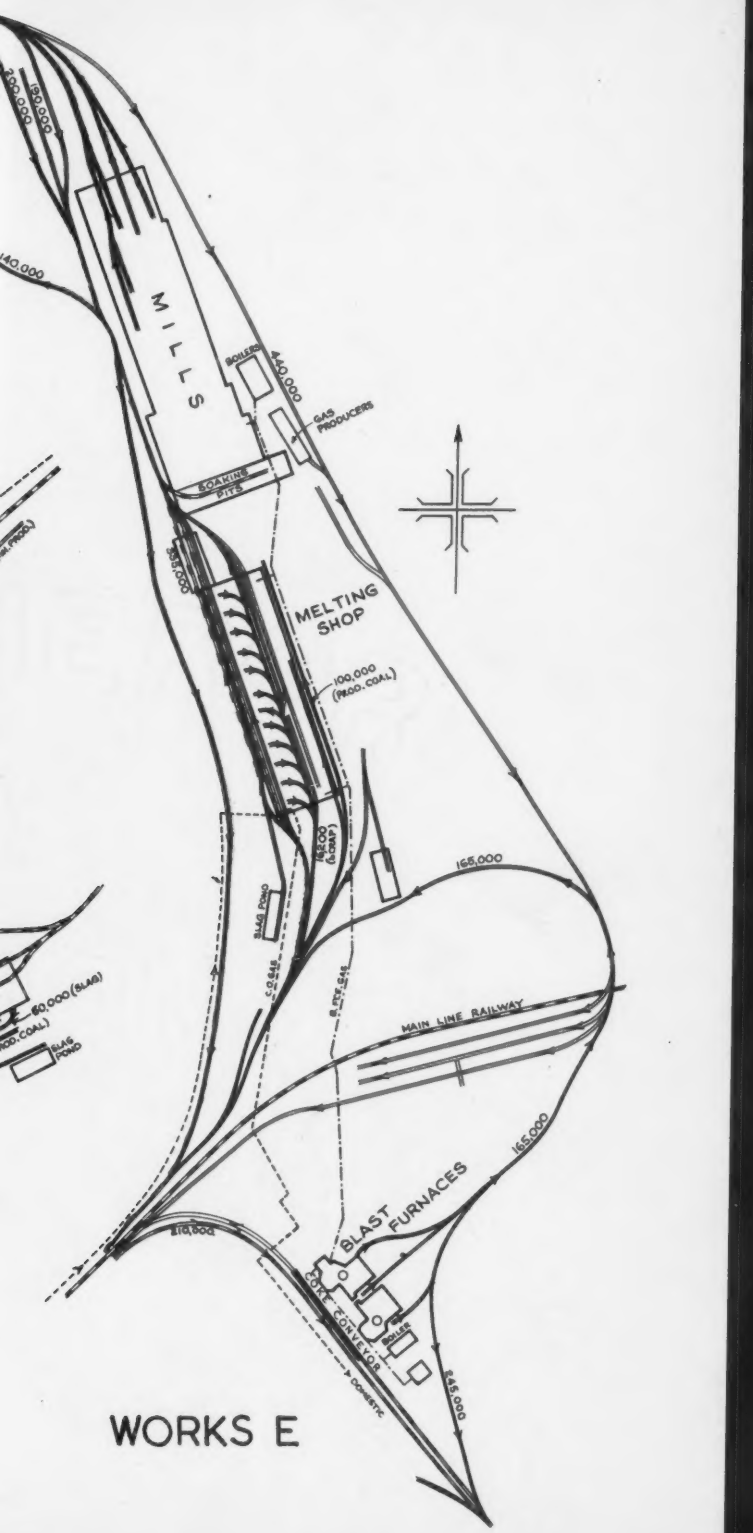
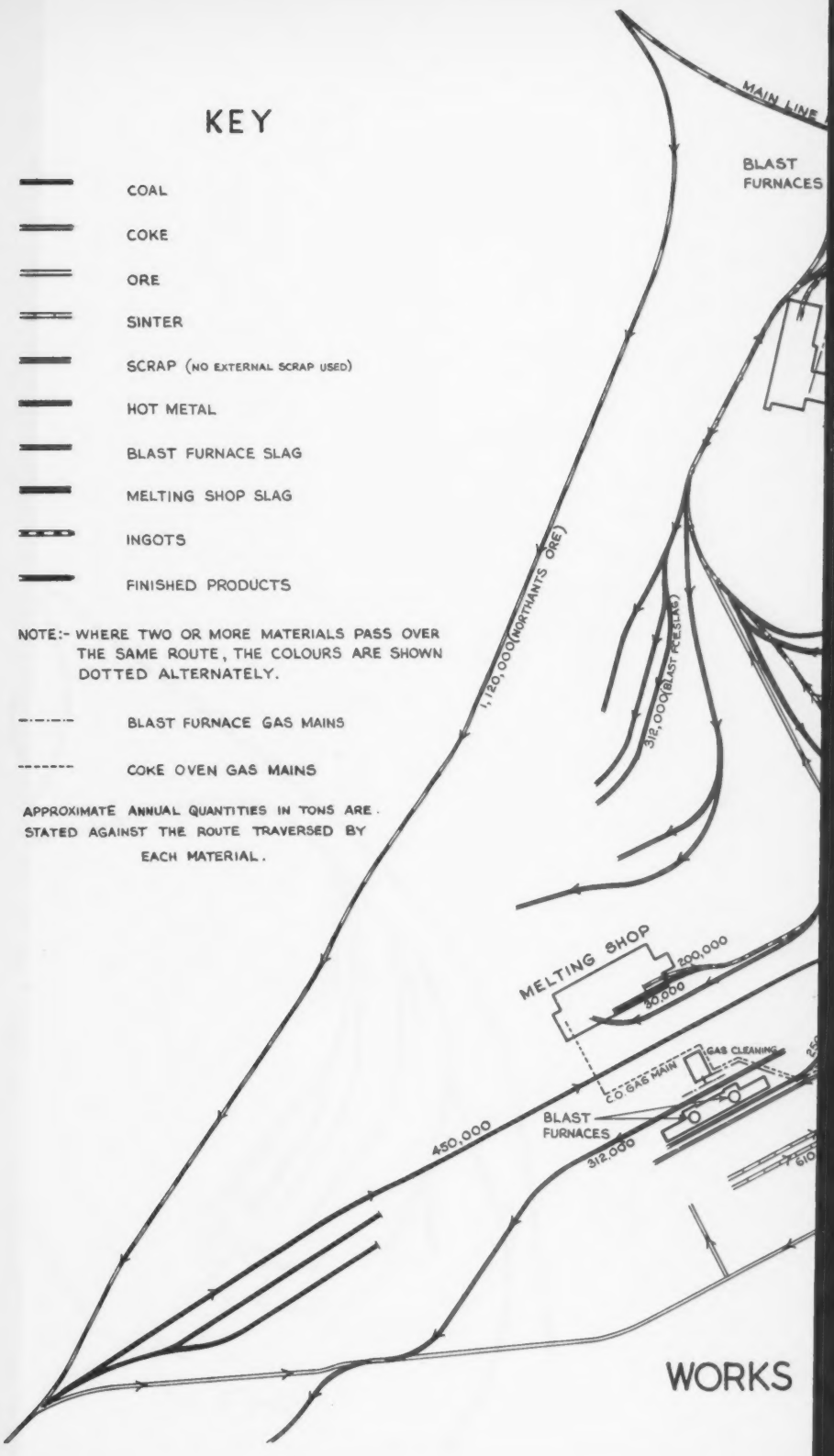


FIG. 18—MATERIALS FLOW DIAGRAMS
(WORKS C, D & E)

FIG. 18


MILLS
BOILERS
440,000
GAS PRODUCERS
SOAKING PITS
MELTING SHOP
100,000 (PROD. COAL)
165,000
MAIN LINE RAILWAY
BLAST FURNACES
245,000
WORKS E


KEY
COAL
COKE
ORE
SINTER
SCRAP (NO EXTERNAL SCRAP USED)
HOT METAL
BLAST FURNACE SLAG
MELTING SHOP SLAG
INGOTS
FINISHED PRODUCTS
NOTE:- WHERE TWO OR MORE MATERIALS PASS OVER THE SAME ROUTE, THE COLOURS ARE SHOWN DOTTED ALTERNATELY.
BLAST FURNACE GAS MAINS
COKE OVEN GAS MAINS
APPROXIMATE ANNUAL QUANTITIES IN TONS ARE STATED AGAINST THE ROUTE TRAVERSED BY EACH MATERIAL.
MAIN LINE
BLAST FURNACES
1,120,000 (NORTHANTS ORE)
312,000 (LAST PEASLAKE)
MELTING SHOP
100,000
30,000
GAS CLEANING
C.O. GAS MAIN
BLAST FURNACES
450,000
312,000
WORKS

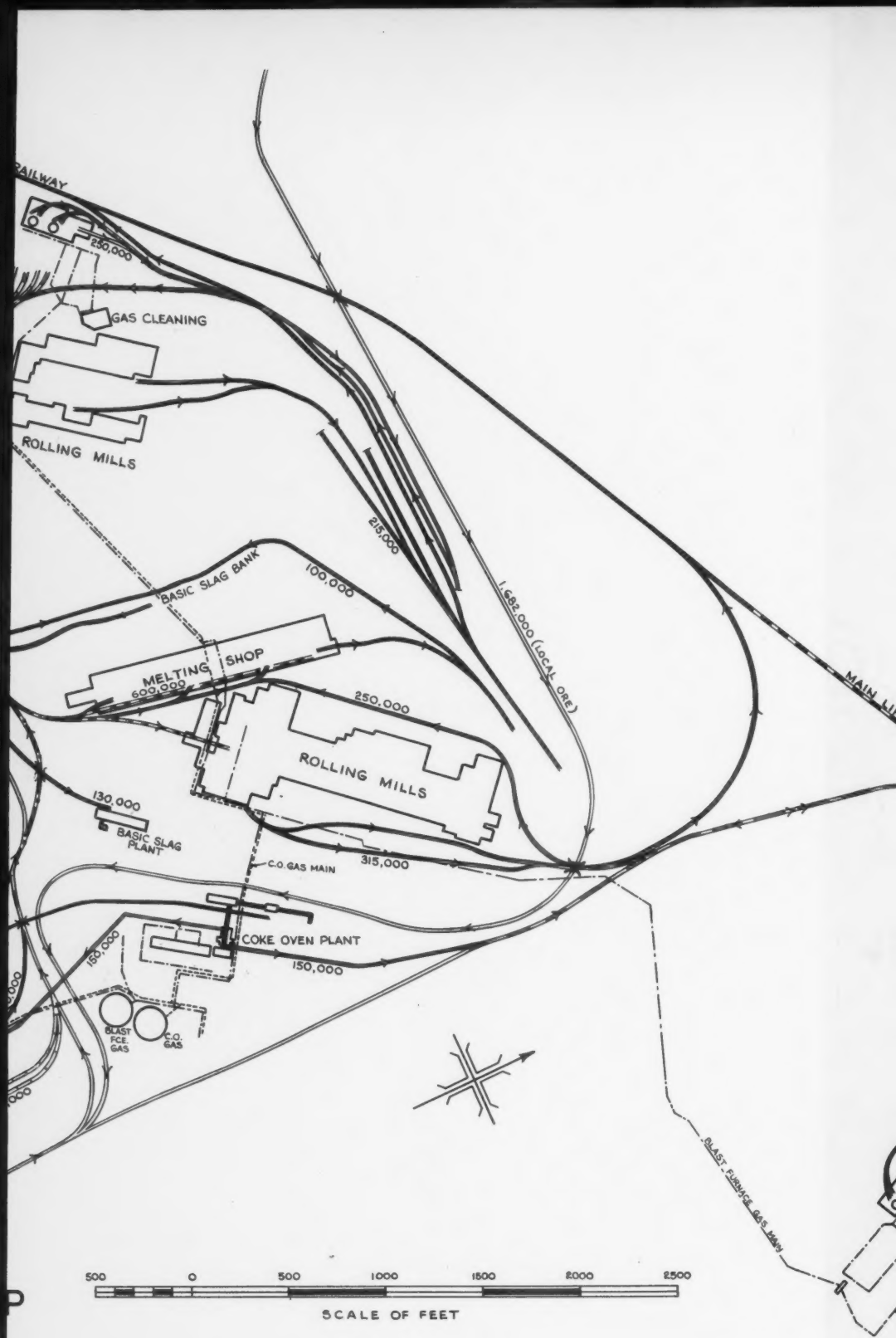
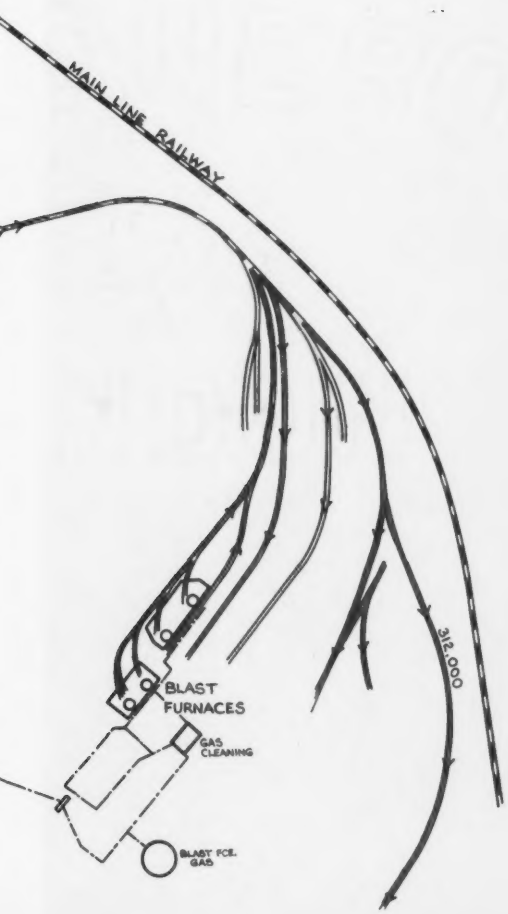
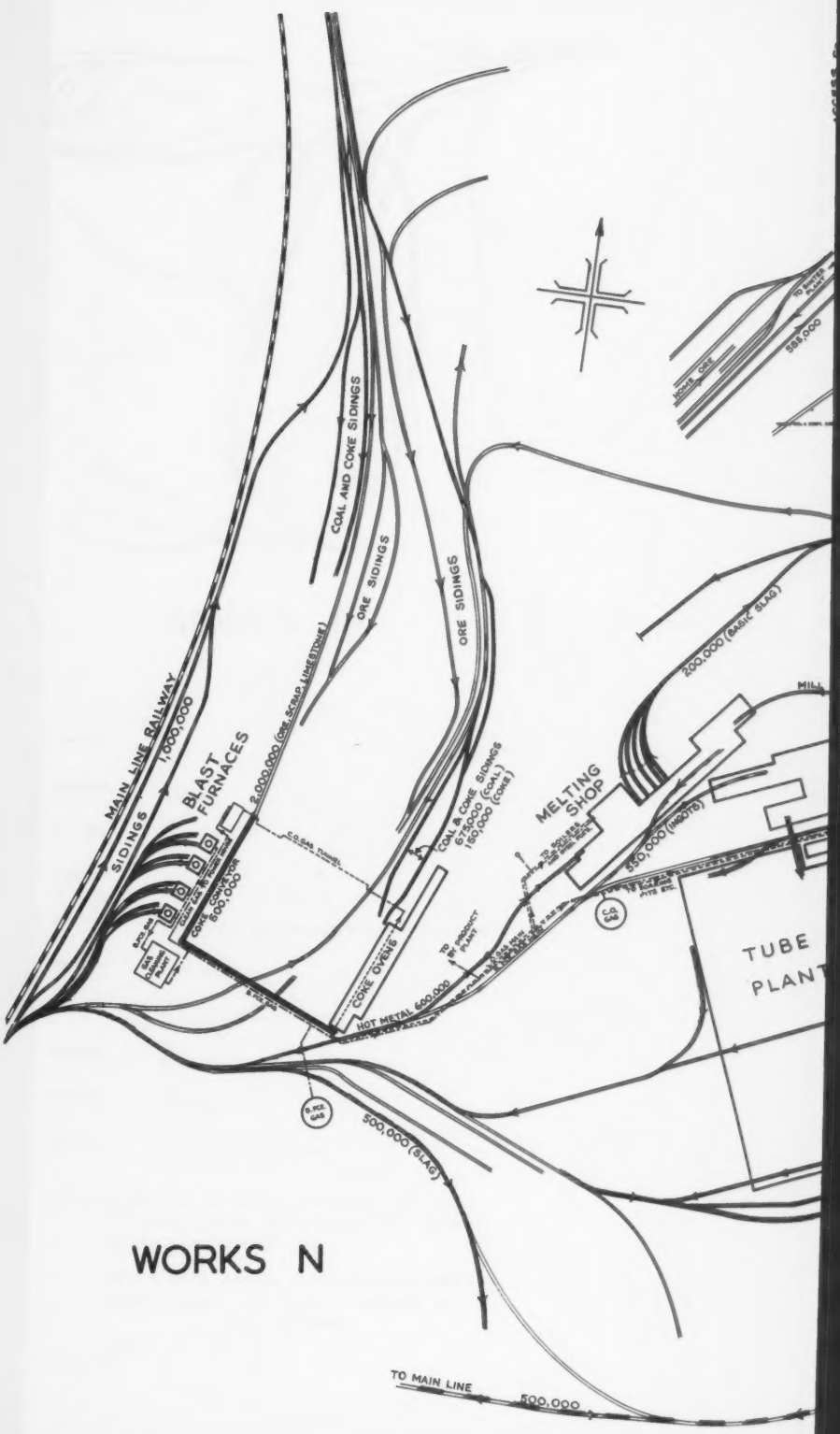


FIG. 19—MATERIALS FLOW DIAGRAM
(WORKS P)

FIG. 19


MAIN LINE RAILWAY
BLAST FURNACES
GAS CLEANING
BLAST FCE. GAS
312,000


MAIN LINE RAILWAY
SIDINGS
1,000,000
BLAST FURNACES
2,000,000 (ORE, SCRAP, LIME STONE)
COAL AND COKE SIDINGS
ORE SIDINGS
ORE SIDINGS
COAL & COKE SIDINGS
(COAL) 175,000
(COKE) 150,000
COKE CONVEYOR
800,000
COKE OVENS
HOT METAL 600,000
MELTING SHOP
650,000 (INGOTS)
200,000 (BASIC SLAG)
TUBE
PLANT
500,000 (SLAG)
TO MAIN LINE
500,000
WORKS N

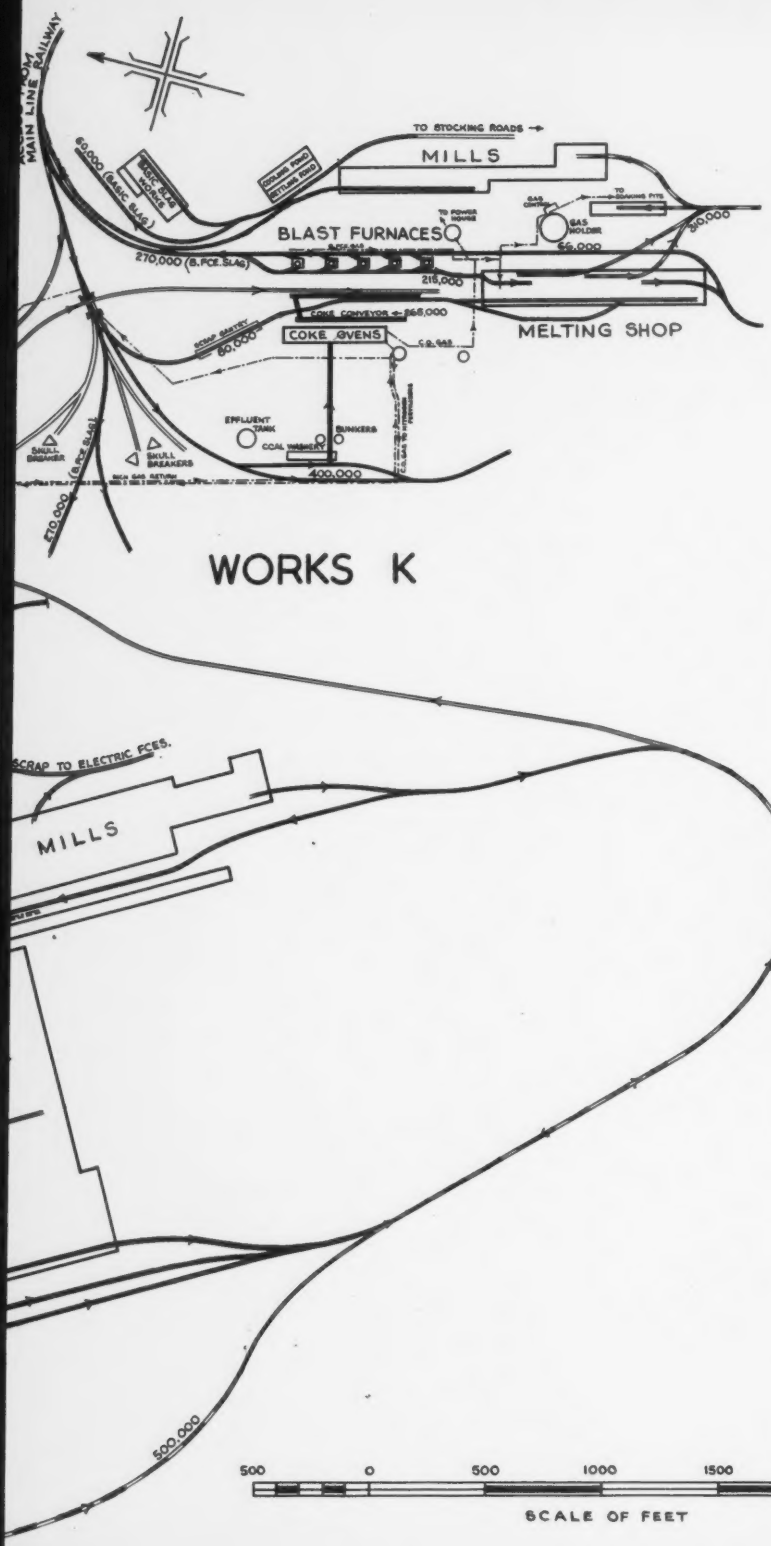
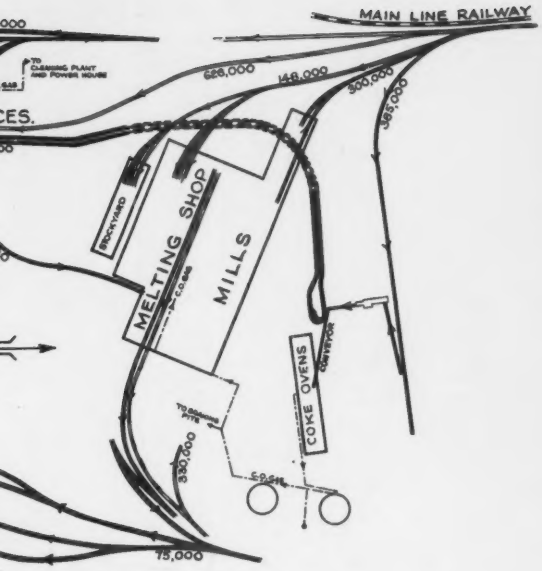


FIG. 20—MATERIALS FLOW DIAGRAMS
(WORKS K, M & N)

FIG. 20



WORKS M

KEY

COAL

COKE

ORE

SINTER

SCRAP (NO EXTERNAL SCRAP USED AT WORKS N)

HOT METAL

BLAST FURNACE SLAG

MELTING SHOP SLAG

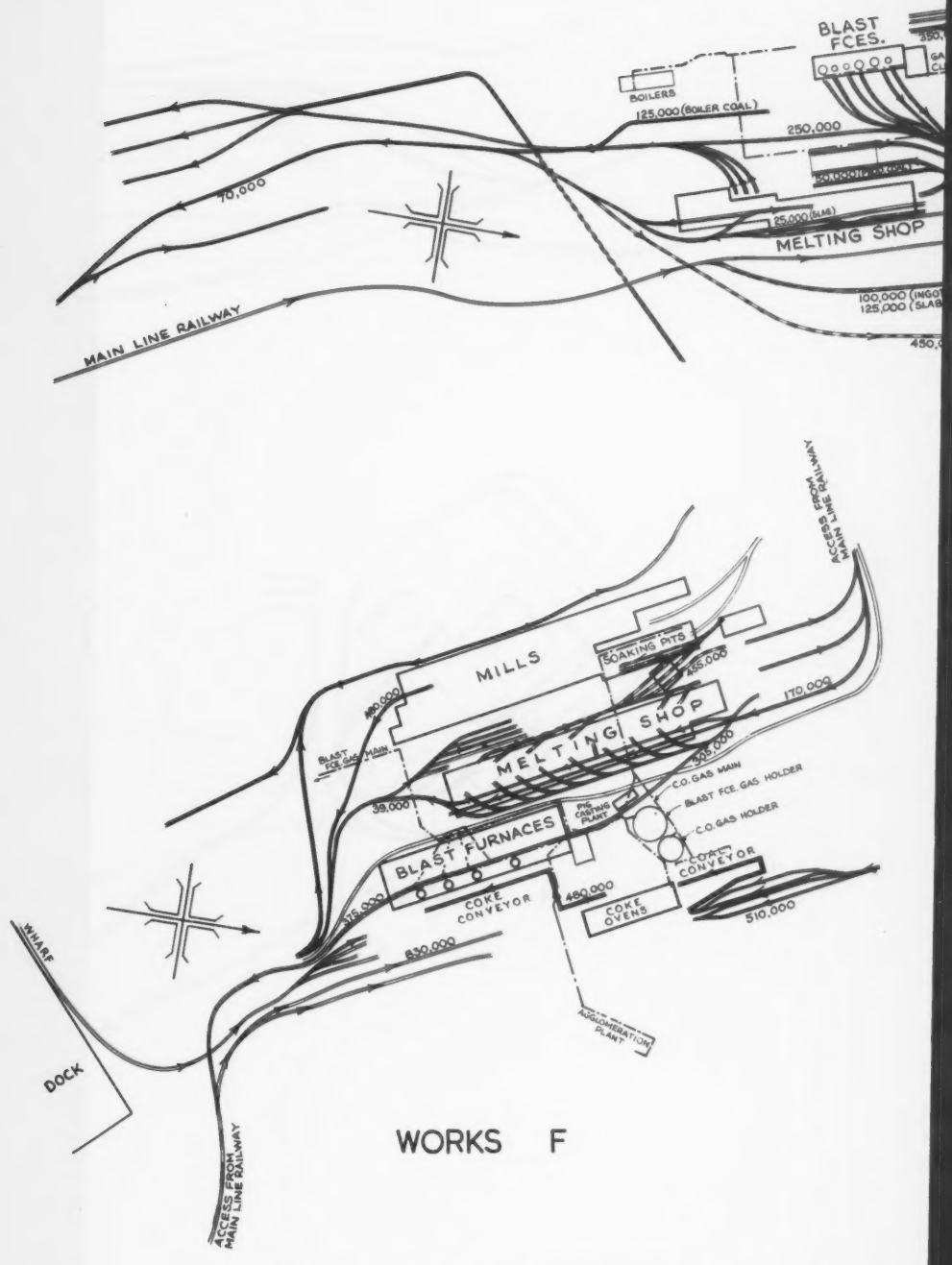
INGOTS

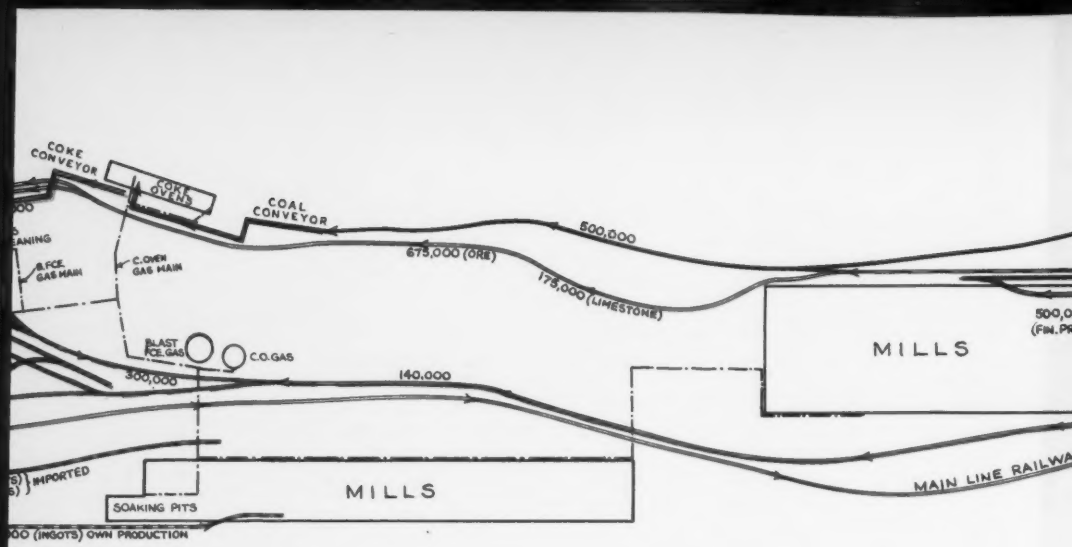
FINISHED PRODUCTS

WHERE TWO OR MORE MATERIALS PASS OVER THE SAME ROUTE, THE COLOURS ARE SHOWN DOTTED ALTERNATELY.

APPROXIMATE ANNUAL QUANTITIES IN TONS ARE STATED AGAINST THE ROUTE TRAVERSED BY EACH MATERIAL.

2500


BLAST FCES.
BOILERS
125,000 (BOILER COAL)
250,000
70,000
25,000 (SLAG)
MELTING SHOP
MAIN LINE RAILWAY
ACCESS FROM MAIN LINE RAILWAY
MILLS
SOAKING PITS
455,000
480,000
170,000
BLAST FCE. GAS MAIN
MELTING SHOP
C.O. GAS MAIN
BLAST FCE. GAS HOLDER
C.O. GAS HOLDER
39,000
PIG CASTING PLANT
BLAST FURNACES
COKE CONVEYOR
COKE OVENS
480,000
510,000
WHARF
DOCK
830,000
AGGLOMERATION PLANT
ACCESS FROM MAIN LINE RAILWAY
WORKS F
500 0 500 1000 1500 2000
SCALE OF FEET

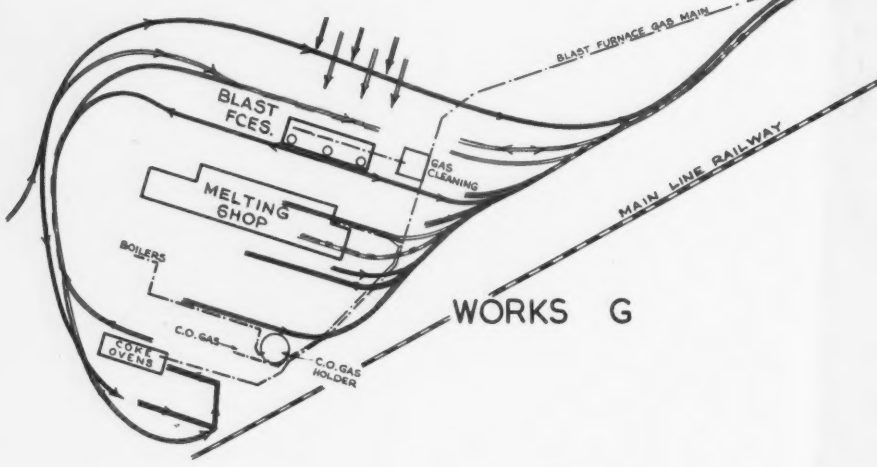


WORKS L

KEY

COAL	BLAST FCE. SLAG
COKE	MELTING SHOP SLAG
ORE	INGOTS
SCRAP	FINISHED PRODUCTS
HOT METAL	

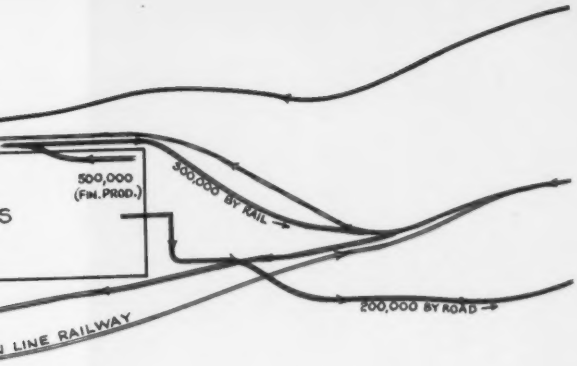
NOTE:- WHERE TWO OR MORE MATERIALS PASS OVER THE SAME ROUTE THE COLOURS ARE SHOWN DOTTED ALTERNATELY. APPROXIMATE ANNUAL QUANTITIES IN TONS ARE STATED AGAINST THE ROUTE TRAVERSED BY EACH MATERIAL.

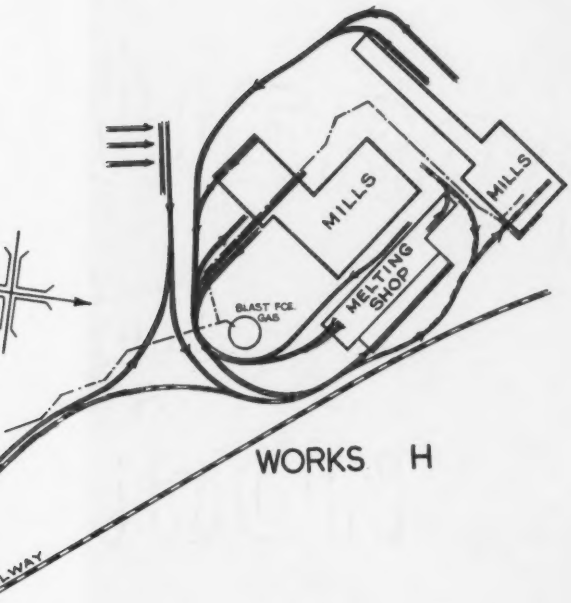


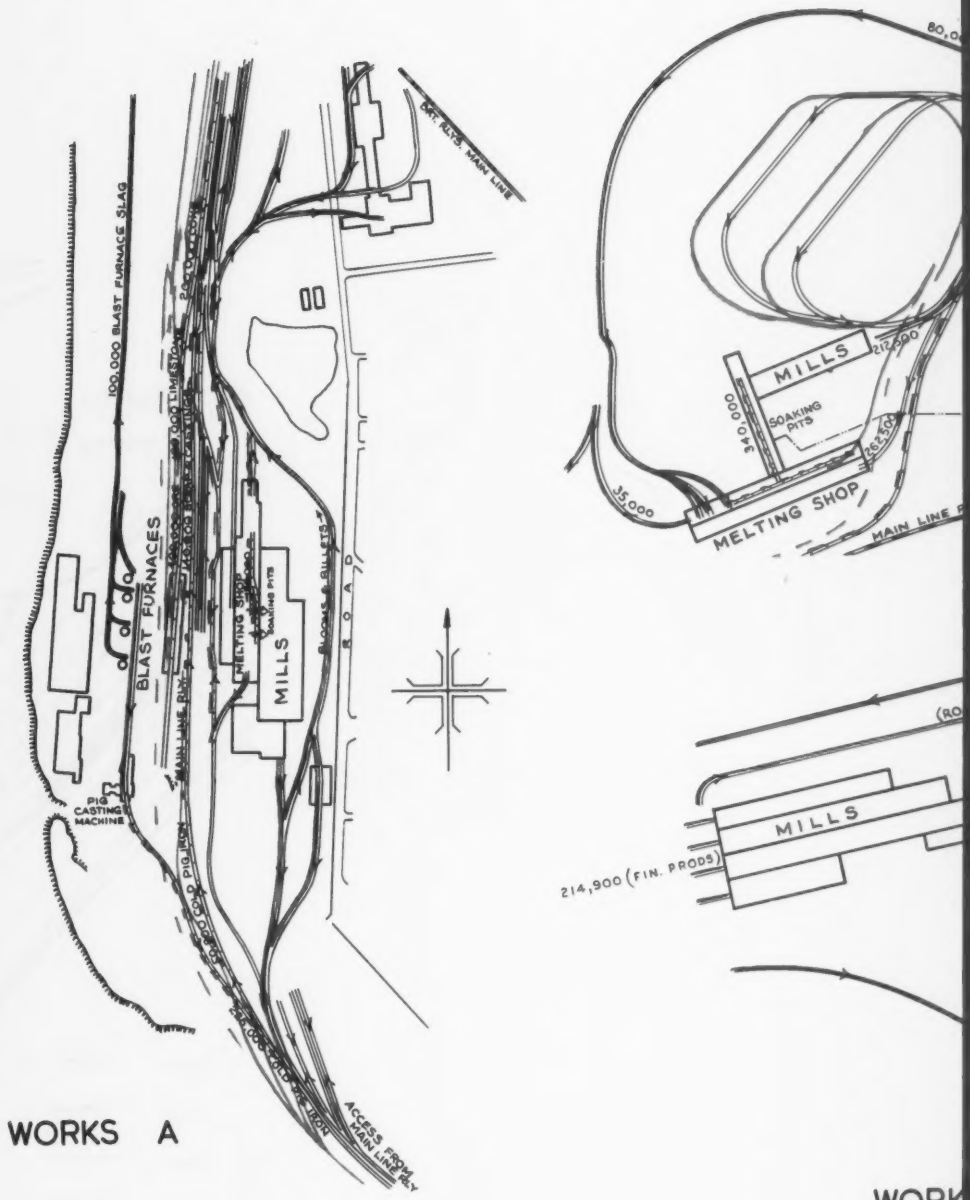
2500

FIG. 21—MATERIALS FLOW DIAGRAMS
(WORKS F, G, H & L)

FIG. 21


500,000
(FIN. PROD.)
300,000 BY RAIL
200,000 BY ROAD
LINE RAILWAY


MILLS
MILLS
MELTING SHOP
BLAST FOR GAS
WORKS H
LWAY



WORKS A

WORK

500 0 500 1000 1500 2000 2500

SCALE OF FEET

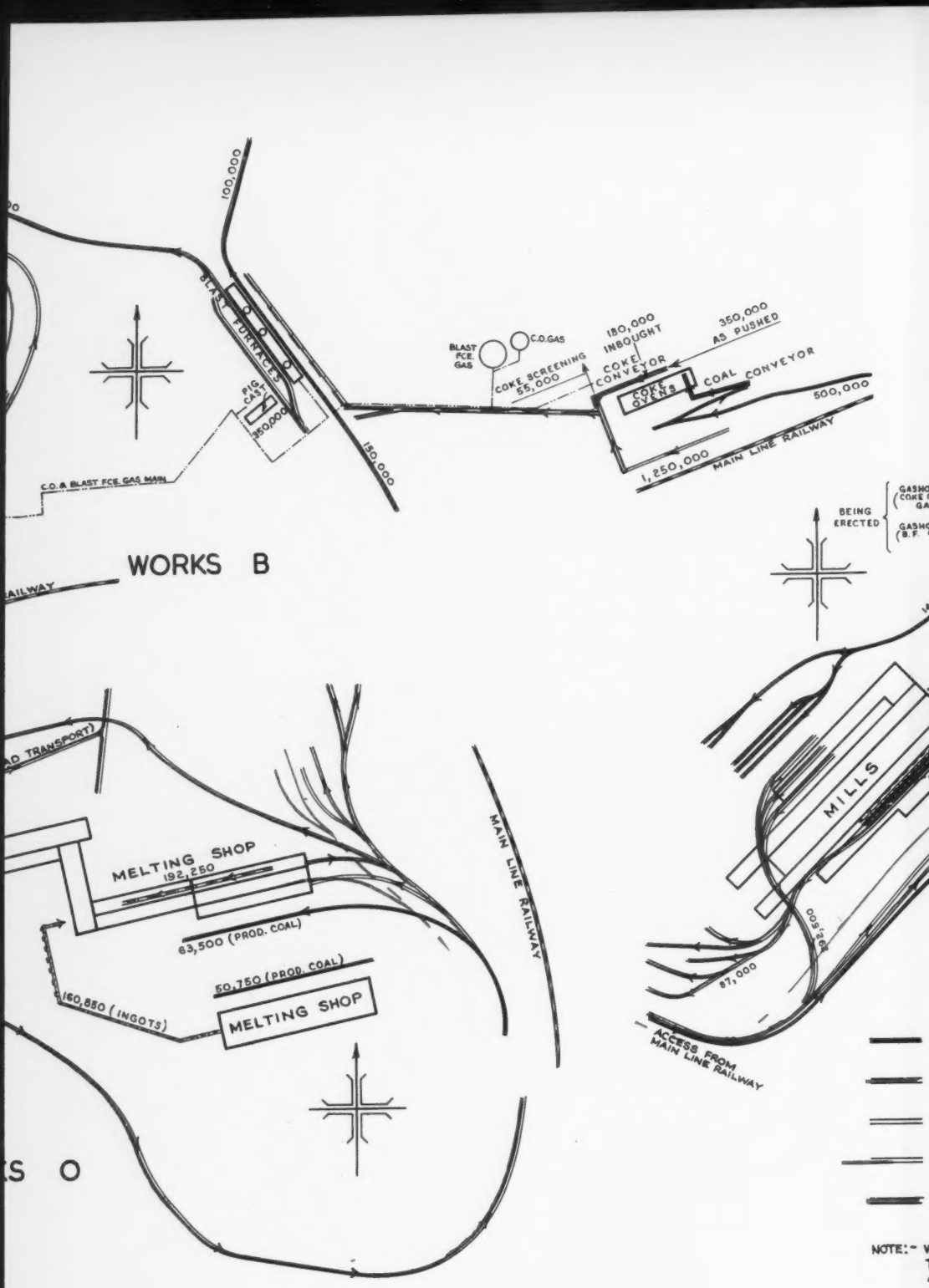
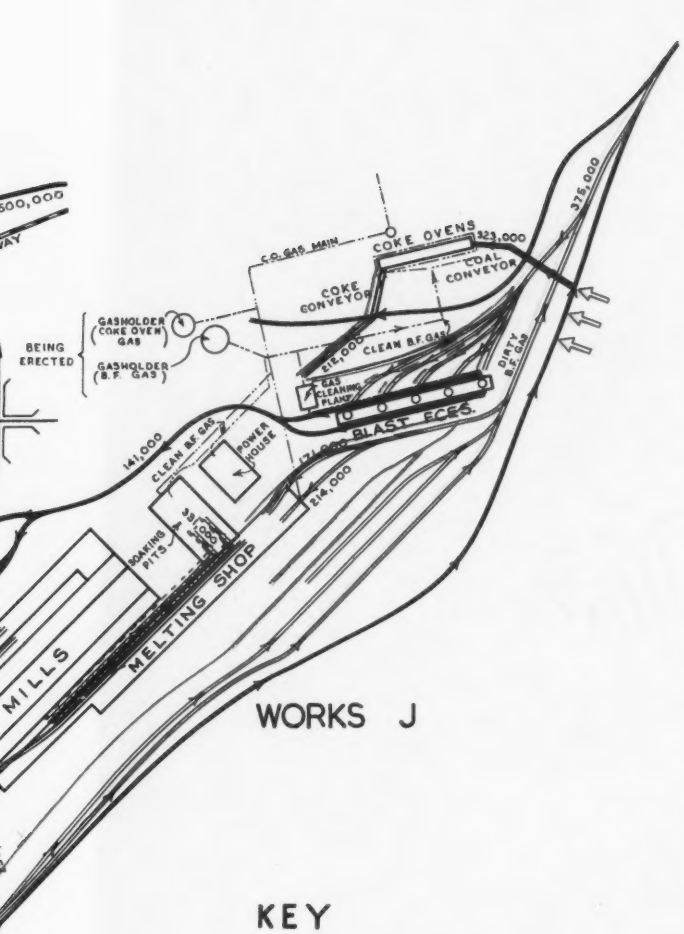
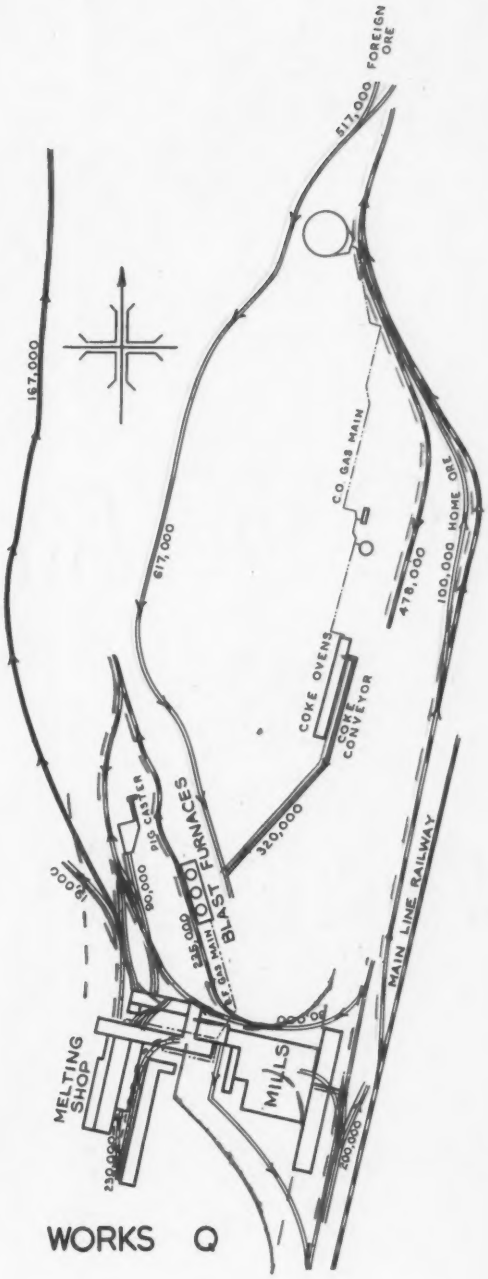


FIG. 22—MATERIALS FLOW DIAGRAMS
(WORKS A, B, J, O & Q)





KEY

COAL	BLAST FCE. SLAG
COKE	MELTING SHOP SLAG
ORE	INGOTS
SCRAP	FINISHED PRODUCTS
HOT METAL	COLD PIG IRON

NOTE:- WHERE TWO OR MORE MATERIALS PASS OVER THE SAME ROUTE THE COLOURS ARE SHOWN DOTTED ALTERNATELY. APPROXIMATE ANNUAL QUANTITIES IN TONS ARE STATED AGAINST THE ROUTE TRAVERSED BY EACH MATERIAL.

artery (requirement No. 5) ; that the units of one type of unit process should be grouped (requirement No. 10) ; and that the units of each group should preferably not be severed by main traffic arteries (requirement No. 11).

Consideration of requirements (4) and (5) shows that they conflict because two traffic arteries may not cross one another at right-angles (requirement No. 7). It therefore becomes desirable to examine the characteristics of the layouts which emerge when this basic arrangement is made to ' evolve.'

Schemes 1·0, 1·1, and 1·2

If requirement No. 4 (there should preferably be direct access between each unit process) is allowed to become dominant, and requirement No. 5 (there should be direct access to each unit from a main artery) is allowed to remain subsidiary, then the traffic arteries must be laid parallel to the axis of the unit processes, and this produces the series of schemes marked 1·0, 1·1, and 1·2. These schemes have the advantage of direct access between each successive unit process, but have the disadvantages that they are not very flexible (since it is not easy to switch from one group to another), and that additional unit processes are severed from their own type of units by main traffic arteries.

Schemes 1·1 and 1·2 differ from scheme 1·0 only by their degree of lateral ' compression.' That is, in scheme 1·1 the units are ' compressed ' until they are at approximately 45° to the main entrance and exit lines ; whilst in scheme 1·2 the units are still further ' compressed ' so that they are parallel to the main entrance and exit lines.

Schemes 1·3 and 1·4

Although schemes 1·3 and 1·4 are not of any practical significance, they have been included to indicate that these are some of the variants which can be derived from the series represented by schemes 1·0, 1·1, and 1·2. Thus by turning the ' outer ' units at 45° in the same direction, scheme 1·3 is the result ; and if these units are still further turned until they are parallel to each other, scheme 1·4 is the result. These variants have all the advantages and disadvantages of the series represented by schemes 1·0, 1·1, and 1·2, and certain others as well. Thus scheme 1·3 largely eliminates right-angled bends, but includes more curves ; scheme 1·4 has the same number of right-angled bends and in addition increases the total number of bends ; it is also more wasteful of space.

It is emphasized that schemes 1·3 and 1·4 are only representative of all the possible variants which can be derived from the series 1·0, 1·1, and 1·2, and which would be too numerous to illustrate.

Schemes 2·0, 2·1, and 2·2

If requirement No. 5 (there should be direct access to each unit from a main artery) is allowed to become dominant, and requirement No. 4 (there should preferably be direct access between each unit process) is allowed to remain subsidiary, then the traffic arteries must be laid parallel to the incoming and outgoing main lines, and this produces the series of schemes marked 2·0, 2·1, and 2·2. These schemes have the disadvantage that direct access between each successive unit process is impracticable and instead, in order to pass from one unit process to the other, shunting *via* a traffic artery becomes necessary. These schemes have the advantages that they are flexible (since it is easy to switch from one group to another), and that additional unit processes are not severed from their own type of units by main traffic arteries.

Schemes 2·3 and 2·4

Schemes 2·3 and 2·4, like schemes 1·3 and 1·4, are not of any practical significance. They have, however, been included to indicate some of the variants which can be derived from the series represented by schemes 2·0, 2·1, and 2·2. In the case of scheme 2·3 the centre units have been ' compressed ' to approximately 45°, and in scheme 2·4 the same units have been further compressed until they are parallel to the main traffic arteries. The variants have all the advantages and disadvantages of the series represented by schemes 2·0, 2·1, and 2·2, and certain others as well. Thus scheme 2·3 is a compromise between schemes 2·0 and 2·1 in the matter of right-angled bends, whilst scheme 2·4 is a compromise between schemes 2·0 and 2·2 and is also more wasteful of space.

It is emphasized that schemes 2·3 and 2·4 are only representative of all the possible variants which can be derived from the series 2·0, 2·1, and 2·2, and which would be too numerous to illustrate.

Schemes 3, 4, 5, 6, and 7

Schemes 3 to 7 are random selections from all possible arrangements and are not especially derived from the two principal series so far considered.

Scheme 3·0 is somewhat similar to scheme 2·2, but access between successive units is effected by mechanical means other than by locomotives and rolling stock on railways. Such mechanical means have, so far, not been satisfactorily developed and the arrangement has therefore to be rejected for the time being. As and when railways can be dispensed with for internal handling, the scheme has considerable advantages. These include (i) the shortest and most direct route between each unit process for the main process materials, and (ii) the fact that only *half* of the ingoing and outgoing materials of the iron-making and steelmaking processes travel over *half* the length of the ' production ' line, thus reducing traffic density within each unit process mentioned. As indicated in Fig. 17, this proposal still permits miscellaneous traffic to be delivered by rail direct to each unit process.

Scheme 4·0 shows the following features :

(1) A ' ring ' or ' belt ' rail system with turn-outs to units on each side is wasteful of space.

(2) Traffic emerges on the main ' ring ' artery where other traffic will be passing in both directions, this ' artery ' traffic being both inter-departmental and main incoming and outgoing.

(3) As drawn, access to the various units for both entry and exit is at the *same* end of each unit process, whereas access should, if at all possible, be at both ends.

(4) This scheme does not easily lend itself to access at both ends of a unit, but if this is arranged, objections (1) and (2) remain.

Scheme 5·0 indicates the inferior arrangement of dead-end curves at all units, including blast-furnaces where they so often occur.

Scheme 6·0 shows that main belt 'arteries,' 'tapered' or 'curved' in plan, do not inherently suit an ordered rectangular arrangement of units.

Scheme 7·0 shows the impracticability of creating a satisfactory layout if the main arteries are made to converge, taper, or radiate.

Schemes 2·5, 2·6, and 1·5

The special feature of scheme 2·5 is that all departments adjoin the exchange sidings. Scheme 2·6 is a variation of scheme 2·5. Scheme 1·5 has some affinity with scheme 1·0, and is used at the Geneva Steelworks in Utah, U.S.A.

Modifications in Layout due to Variation in Output

In the foregoing schemes the broad principle adopted is for each ironmaking unit to serve one set of steelmaking and rolling-mill units. The opinion is held by some that it is more economical to build and operate units of ironmaking plant which are large in their output by comparison with the optimum size of steelmaking units. In this way, depending on what is considered to be the optimum size of a steelplant, the ironmaking unit will then preferably be grouped with a number of units (say, from 3 to 4) of steelmaking and mills.

In amplification of the above, one contention is that the best size of steelmaking plant for maximum efficiency is about 15,000 ingot-tons per week, and that for control and management, rolling-mill units having the same capacity should be closely associated with these steelmaking units. A somewhat divergent view is also held, namely, that if sufficient hot metal is available, steelplants having capacities of the order of 30,000 ingot-tons per week can be operated efficiently. Such differences, however, merely alter the scale and not the principle of multiple steel and mill units being served by one ironmaking unit, which, in this contention, is envisaged as at least six large blast-furnaces having a production of 30,000 to 40,000 tons of iron per week.

So far as the optimum grouping of the blast-furnaces is concerned, the evidence is not conclusive, since the number in a group has been limited by other authorities to four blast-furnaces.[4] However, the principle remains that the output of the ironmaking unit may be potentially higher than the capacity of one steelmaking unit.

If the difference in area required for balanced production in the three stages is conceded, then the tentative layouts 1·0 to 7·0 require some modification, and this has been made in schemes 1·0*a*, 1·1*a*, 1·2*a*, 1·5*a*, 2·1*a*, 2·2*a*, 2·5*a*, and 2·6*a*. These schemes have generally the characteristics described for the comparable schemes with the corresponding reference numbers. Schemes 2·5*a* and 2·6*a* incorporate many of the important requirements already enumerated, and particularly requirement No. 14, namely, that all units should be as close as possible to the main railway line.

Conclusion

Concerning the probable best arrangement, it is clear that the choice is largely dependent upon which of the requirements the designer wishes to lay emphasis. Also, until these tentative layouts can have their merits assessed from the point of view of traffic, in addition to the criteria already discussed, it is not practicable to assert which layouts are necessarily the best to recommend. The authors are inclined to the opinion that where railways are retained as the essential means of transport between the various departments or unit processes, schemes 1·0*a*, 1·1*a*, 1·5*a*, 2·1*a*, 2·2*a*, 2·5*a*, and 2·6*a* have commendable features.

If, at some future date, railways can be dispensed with, in favour of other mechanical means for transporting the main process materials, then scheme 3 has the merit of providing the shortest route between each unit process, which is a considerable advantage.

AMPLIFICATION OF POSSIBLE LAYOUTS (BLOCK PLANS)

The object of Fig. 17 is to show to the larger scale of 1 in. = 1650 ft. the possible amplification of certain of the schemes outlined in the block plans in Fig. 16. It is emphasized that the arrangement of such buildings and plant as are shown in Fig. 17 is not intended in any way to be the best detail for any unit process : firstly, because there are numerous items of buildings and plant which are not shown and, secondly, because the detailed layout will be subject to the results of other investigations now being made. The details in Fig. 17 are accordingly given for the sole reason of showing a skeleton outline of the type of plant visualized in the block plans in Fig. 16.

MATERIAL FLOW THROUGH EXISTING WORKS

It has already been emphasized that the qualities of a layout are measured by the degree of efficiency with which the materials can be transferred from one unit process to another. In making any such assessment, therefore, an overall impression must first be obtained as to the way in which the works will be operated (comparable, in fact, with a machine).

In view of the complexity of the materials to be handled, it is not possible to memorize the routes for simultaneous consideration, but it is practicable if the routes are depicted in colour and if the tonnage is indicated. This has therefore been effected (in Figs. 18 to 22) for the principal materials in the works under consideration, and has enabled a comparison to be made which would otherwise have been impossible. It will be seen that the diagrams provide an immediate and striking impression of the way in which the works are operated and that the colouring assists in indicating (*a*) which routes are economic or otherwise, and (*b*) points where congestion is likely to occur.

In reading the diagrams, due allowance must be made for the fact that the traffic flow is intermittent, for the frequency and size of the loads, and the question as to whether the loads will be in or out of phase. Such considerations may, at this stage, be made in a general way, but more detailed consideration will

have to be left to the subsequent traffic investigation suggested later in this paper. The authors wish to stress that this aspect of traffic analysis will also, they believe, prove to be a means of assessing the value of a layout.

The approximate annual tonnages are useful to convey an idea of the magnitude of the traffic, since the volume and extent of the traffic lines must ultimately be related to the primary output of iron and steel. The annual tonnages of the principal materials have been indicated on the material flow diagrams chiefly for the purpose of conveying the scale of the volume of traffic. This information has enabled the authors to prepare, in Table XII, factors which, very broadly, are a measure of the 'operability' of the layout.

As a measure of *total cost* of traffic handling, a computation of the 'energy' factor of ton-miles of raw material per ton of finished product is not considered[2] adequate, but as a first approximation with the information available some interesting results have been obtained in Table XII and these have been plotted on the accompanying graphs in Table XII.

It will be noted that Table XII is an abridged summary, as it is considered that the reproduction of the tonnages and lengths of haul and their arithmetical products in ton-miles (RL), evaluated separately for each raw material, would necessitate too much detail. It is of interest to note that the complete 'energy' factor (horse-power-hours per ton), which is deemed to be proportional to the handling costs, is calculated by Mr. G. A. V. Russell[7] in his paper on this subject, but this necessitates the addition of an assumed value for work against gravity. This value is assumed by Mr. Russell to be constant, but it is evident that for British works this assumption would be incorrect. As this factor, which is required to allow for work against gravity, is as important in magnitude as the energy expended in horizontal movement, the authors consider it advisable to wait until actual values can, if at all possible, be obtained at some later date.

From the point of view of layout, *i.e.*, arrangement of the processes of ironmaking, steelmaking, and rolling mills relative to one another, this basis of ton-miles per ton enables the layout to be visualized in terms of actual figures. Thus, apart from the other consideration of work against gravity, it is axiomatic that the factor of ton-miles per ton should be as low as possible. This, however, is governed not only by the average length of haul of the raw materials, but is also determined by the quantity of raw materials to be handled per unit quantity of finished product, which, for convenience in this paper is termed the yield.

In other works the energy factor of ton-miles per ton may be large owing to a long average haul, but it may also be large owing to a large quantity of raw materials required by the process (*e.g.*, home ores *versus* foreign ores). The extent to which these two variable functions affect the final energy factor has been brought out visually in the three graphs for ironmaking, steelmaking, and ironmaking and steelmaking combined. As examples of the way in which the graphs should be read, consider works C. Here the energy factor ($\Sigma RL/P$) is low because the two factors of length of haul and of yield are acting in the same sense, *viz.*, a *low* length of haul and a *high* yield. Considering the other extreme, works P, the energy factor is high because the length of haul and the yield are also acting in the same direction, *viz.*, a *high* length of haul and a *low* yield.

Reasons for the values of the various works may be ascertained by inspection of Table XII and the material flow diagrams (Figs. 18 to 22). To take a case in point, consider works K ; this would have had a low energy factor because the yield is almost equal to the average, and the works itself is compact, but the haul has been increased by the fact that the incoming sidings are at a considerable distance ; the energy factor has therefore risen. The values for other works may also be accounted for by reason of their configuration or process (*i.e.*, yield).

The values of the three functions ($\Sigma RL/P$), ($\Sigma RL/\Sigma R$), and ($P/\Sigma R$), may be compared in each case with the average for all the works considered, as this forms a useful basis of comparison. The approximate value of these functions for any given total production (P) having any given yield ($P/\Sigma R$) for any new or existing works may usefully be compared with the values set out in Table XII and in the accompanying graphs in Table XII.

In the calculations included in this section of the paper, the movement of finished products from the rolling mills is excluded. Although this is of lesser magnitude than for the ironmaking and steelmaking departments, its comparative size should be appreciated because in many existing layouts a short run for outgoing products is only achieved at the expense of a long run with the much larger tonnages of raw materials required to make that product. The authors regret that it has not been possible to add these calculations before going to press, but, it is hoped that they may be included in any further investigation which may be made.

CONCLUSIONS

As mentioned in the introduction, it has been impracticable to cover all the aspects which should be considered in the layout of an iron and steel works and these include the following :

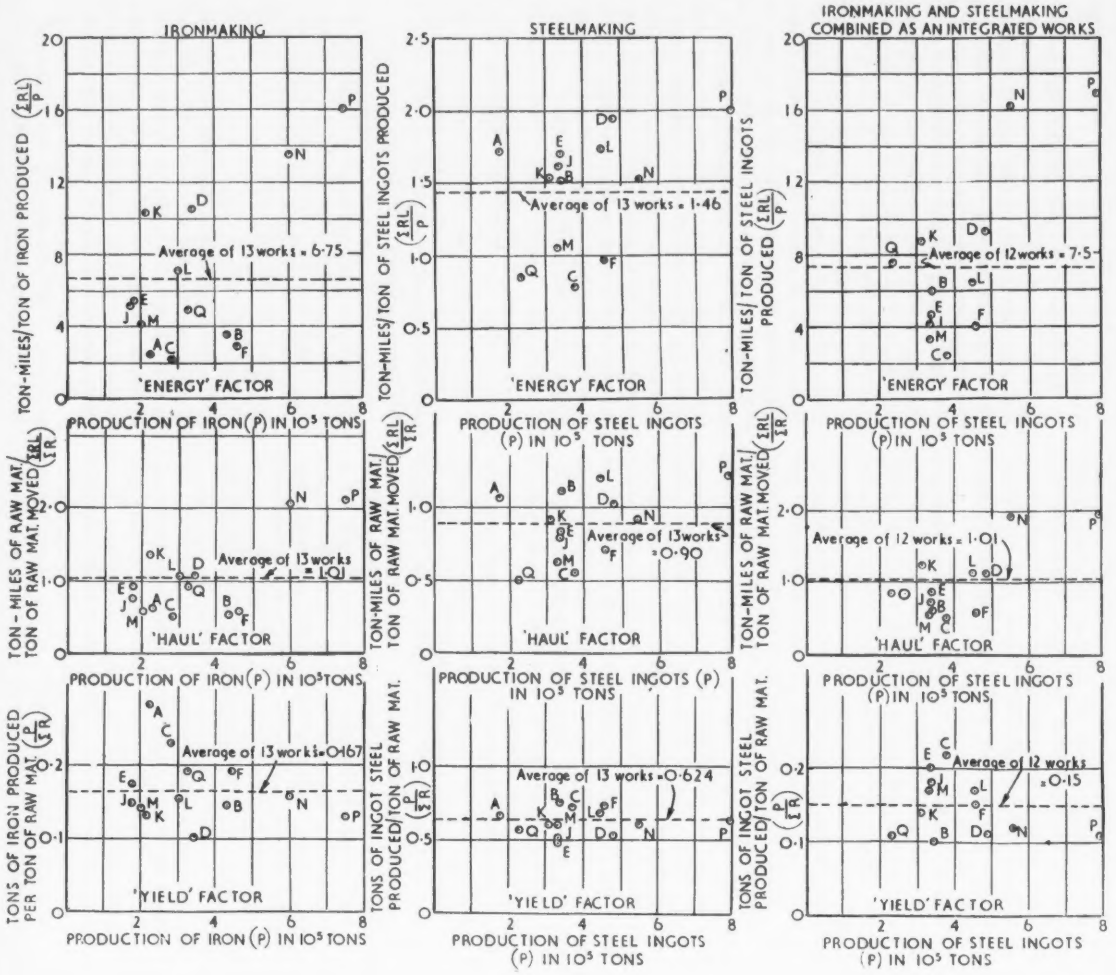
Mechanical handling	Welfare, maintenance, and stores
Bridges and weighbridges	Drainage and fencing
Generation and distribution of power	Housing and transport
Methods of control for plant, traffic, and operatives	Administration and research buildings

(1) Apart from considerations of national policy (*e.g.*, economic and strategic), the governing factors in the selection of a site are that access to raw and other materials and to present and future markets is most favourable, coupled with the availability of adequate labour, power, and water supplies (p. 328).

(2) The site should (*a*) be free from natural and artificial obstructions, (*b*) be preferably level, (*c*) have a firm sub-stratum, (*d*) have a low ground-water level, and (*e*) be unrestricted by any surrounding

Table XII

MATERIAL FLOW THROUGH EXISTING WORKS


IRONMAKING
STEELMAKING
IRONMAKING AND STEELMAKING COMBINED AS AN INTEGRATED WORKS
TON-MILES/TON OF IRON PRODUCED (ΣRL/P)
TON-MILES/TON OF STEEL INGOTS PRODUCED (ΣRL/P)
TON-MILES/TON OF STEEL INGOTS PRODUCED (ΣRL/P)
Average of 13 works = 6·75
Average of 13 works = 1·46
Average of 12 works = 7·5
'ENERGY' FACTOR
PRODUCTION OF IRON (P) IN 10³ TONS
PRODUCTION OF STEEL INGOTS (P) IN 10³ TONS
TON-MILES OF RAW MAT./TON OF RAW MAT. MOVED (ΣRL/ΣR)
Average of 13 works = 1·01
Average of 13 works = 0·90
Average of 12 works = 1·01
'HAUL' FACTOR
TONS OF IRON PRODUCED PER TON OF RAW MAT. (P/ΣR)
TONS OF INGOT STEEL PRODUCED/TON OF RAW MAT.
Average of 13 works = 0·167
Average of 13 works = 0·624
Average of 12 works = 0·15
'YIELD' FACTOR
PRODUCTION OF IRON (P) IN 10³ TONS
PRODUCTION OF STEEL INGOTS (P) IN 10³ TONS
PRODUCTION OF STEEL INGOTS (P) IN 10³ TONS

The method of compiling the table is described in the text. All figures are approximate. Quantities are in approximate annual tonnages as received from the works, except in a few instances where details were not available. The results are plotted graphically in the accompanying figure. The significance of the figures is described in the text.

Raw materials include :

Ironmaking—Coal, coke, ore, limestone, basic slag, skulls, scrap, cinder, sinter, etc., and blast-furnace slag.

Steelmaking—Hot metal, pig, scrap, oxides, fluxes, fettlings, fuel, finishings, anthracite, etc., and melting-shop slag.

Ironmaking and Steelmaking Combined—Sum of raw materials for ironmaking and steelmaking.

P = Annual tonnage of product.

ΣR = Total annual tonnage of raw materials required to produce P tons of product.

L = Length of 'haul,' in miles, for each raw material.

$\Sigma RL/P$ = 'Energy,' *i.e.*, ton-miles of raw materials per ton of finished product.

$\Sigma RL/\Sigma R$ = 'Haul,' *i.e.*, ton-miles of raw materials per ton of raw material.

$P/\Sigma R$ = 'Yield,' *i.e.*, tons of finished product per ton of raw material.

Table XII (*continued*)

Works	Ironmaking					Steelmaking					Ironmaking and Steelmaking Combined					
	Hot Metal and Pig Iron	Total Raw Materials	Ratio	Ratio	Ratio	Ingots	Total Raw Materials	Ratio	Ratio	Ratio	Ingots	Total Raw Materials	Total	Ratio	Ratio	Ratio
	Tons	Tons	Ton-mls./ton of Pig Iron	Ton-mls./ton of Raw Mats.	Tons Fin. Prod./ton Raw Mats.	Tons	Tons	Ton-mls./Ingot ton	Ton-mls./ton of Raw Mats.	Tons Fin. Prod./ton Raw Mats.	Tons	Tons	Ton-mls. Raw Materials	Ton-mls./ton of Ingots	Ton-mls./ton of Raw Mats.	Tons Fin. Prod./ton Raw Mats.
	P	ΣR	$\frac{\Sigma RL}{P}$	$\frac{\Sigma RL}{\Sigma R}$	$\frac{P}{\Sigma R}$	P	ΣR	$\frac{\Sigma RL}{P}$	$\frac{\Sigma RL}{\Sigma R}$	$\frac{P}{\Sigma R}$	P	ΣR	ΣRL	$\frac{\Sigma RL}{P}$	$\frac{\Sigma RL}{\Sigma R}$	$\frac{P}{\Sigma R}$
A	225,000	800,000	2·20	0·62	0·282	180,000	272,800	1·72	1·13	0·660			Not Applicable			
B	430,000	2,925,000	3·56	0·52	0·147	340,000	451,300	1·51	1·14	0·755	340,000	3,376,300	2,042,300	6·0	0·61	0·10
C	282,000	1,224,100	2·17	0·50	0·230	377,500	516,800	0·78	0·57	0·731	377,500	1,740,900	908,400	2·4	0·52	0·22
D	343,800	3,364,800	10·51	1·07	0·102	486,018	905,100	1·98	1·06	0·537	486,018	4,269,900	4,574,560	9·4	1·07	0·11
E	174,497	1,001,700	5·36	0·93	0·174	335,000	694,200	1·70	0·82	0·483	335,000	1,695,900	1,503,949	4·6	0·89	0·20
F	459,304	2,394,294	2·95	0·57	0·191	457,048	635,800	0·98	0·71	0·719	457,048	3,030,094	1,804,900	4·0	0·60	0·15
G								Quantities Not Available								
H								Quantities Not Available								
J	171,000	1,171,200	5·11	0·75	0·146	335,632	671,100	1·63	0·81	0·500	335,682	1,842,300	1,418,480	4·2	0·77	0·18
K	215,000	1,637,000	10·31	1·36	0·131	309,100	509,300	1·54	0·93	0·607	309,100	2,146,300	2,700,170	8·7	1·25	0·14
L	300,000	1,961,700	7·04	1·08	0·153	450,000	644,400	1·74	1·22	0·698	450,000	2,606,100	2,902,540	6·5	1·12	0·17
M	200,000	1,434,000	4·11	0·57	0·140	330,000	541,000	1·05	0·64	0·610	330,000	1,975,000	1,170,400	3·5	0·59	0·17
N	600,000	3,775,000	13·58	2·08	0·159	550,000	911,400	1·52	0·92	0·604	550,000	4,686,400	8,988,660	16·3	1·92	0·12
O			No Blast-Furnaces Exist										Insufficient Information			
P	750,000	5,678,000	16·08	2·13	0·132	800,000	1,312,300	2·02	1·23	0·609	800,000	6,990,300	13,670,250	17·1	1·95	0·11
Q	325,000	1,707,000	4·87	0·93	0·191	230,000	386,500	0·84	0·50	0·595	230,000	2,093,500	1,776,100	7·7	0·85	0·11

natural or artificial features in order to allow for extension (p. 328).

(3) The optimum layout is that which enables the various materials to be delivered to their destination in the plant at the time when they are required, and which also enables the finished and waste products to be subsequently cleared as efficiently and as economically as possible (p. 330).

(4) Material flow lines, considered in their broadest sense as general trends, and not necessarily as individual railway tracks or conveyor systems, should preferably be smooth and without contra-flow. They may therefore change direction in their course through the works, provided that the unit processes are maintained in consecutive order (p. 330).

(5) Layouts in general conform to two principal types, namely, the 'herringbone' and the 'ring' formations (*see* Fig. 7). Consideration shows that each individually has advantages and that neither is wholly superior to the other (p. 332).

(6) The shape of a site for a new works should preferably be a well-proportioned rectangle. Arrangements for the receipt and dispatch of materials by rail should broadly include holding-sidings close to each department or unit process of the works, with segregated routes for traffic between these holding-sidings and the main incoming and dispatch exchange-sidings (through which access is obtained to the main railway system). The incoming and dispatch exchange-sidings should preferably be separate, and each should have not less than two points of contact with the main railway system.

The number of tracks at each point of contact with the main railway system will depend on the quantity of materials to be handled ; only one track at each point of contact may be necessary (p. 333).

(7) To achieve the optimum layout described in (3) above, the arrangement of the individual items of buildings and plant and of the unit processes (or departments of the works) should be such as to induce an ordered flow of material through the works, and they should, therefore, it is considered, be preferably parallel, or at right-angles, to defined axes of the whole works, as described and illustrated in Table V and in Fig. 5 (p. 333).

A regular plan should be adhered to, even at the expense of some excavation or filling (p. 333).

(8) An integrated works should preferably be arranged so that the three main departments of ironmaking (a_1, a_2, etc.), steelmaking (b_1, b_2, etc.), and rolling mills (c_1, c_2, etc.), are capable of completely using the products of each department in turn (*see* Fig. 8). Each department will comprise as many groups of units ($a_1 + a_2$, etc., $b_1 + b_2$, etc.) as are necessary to make up the aggregate total output demanded from the works (*see* Fig. 8). If, in course of time, due to changes in output of certain items of plant, one department (b, say) cannot absorb the output of the preceding department, then additional units may be added as required to the department concerned (*see* Figs. 8 (i) and 8 (iv)).

As an alternative to extension in one direction from one side of the site, as in Figs. 8 (i) and 8 (ii), consideration might be given to locating the initial plant about the longitudinal centre-line of the proposed site, successive extensions to the units being placed alternately about the centre, as in Figs. 8 (iii) and 8 (iv), thus preserving a final symmetrical layout (p. 335).

(9) Arrangements for the reception of ore and limestone are complicated by numerous factors. These include the use, at any one works, of a large number of ores, from both home and overseas, which may require careful preparation and blending before and after stocking.

In view of the diversity of the factors, the whole subject of ore reception, handling, and preparation, including crushing, screening, blending, and sintering, warrants further consideration. It is therefore impracticable at this stage to formulate firm recommendations for the relative position of stockyard and high-line bunkers. The authors, however, consider that the arrangement in which the wharf (or rail siding), stockyard, and high-line bunkers adjoin, may often seem to have considerable advantages (p. 335).

(10) Transfer of coal and coke by conveyor is widely adopted, and it would appear that the most efficient methods of mechanical handling have been achieved for these materials (p. 339).

(11) The requisite sizes and relative location of the main and reserve stockyards, together with the methods of filling and unloading them, are integral with the whole subject of ore reception referred to in (9) above, and these accordingly warrant further consideration before formal recommendations can be made (p. 339).

(12) Coke ovens should be situated in the line of flow of materials to the high-line bunkers. 'Through' rail tracks should not be laid near the benzol plant owing to the risk of fire (p. 340).

(13) The inclined, balanced twin-skip hoist is the most efficient method of blast-furnace charging, in contrast with (say) one version of the Pohlig system, which requires the use of locomotives. The relative position of the bunkers and blast-furnaces is therefore determined by the requirements of the skip hoist, and with adequate allowance for the efficient arrangement of other services to and from the blast-furnace plant (p. 342).

(14) The capacity, arrangement, and location of the ore-treatment plant are important components of the ore-reception layout referred to in (9), and must therefore receive further consideration before any specific recommendation can be offered (p. 342).

(15) To attain the most efficient degree of operation there is some indication that blast-furnaces should be grouped, but, as yet, there is little evidence to determine the exact size and number in each group, although the latter is believed to be four. It is also impracticable to recommend one arrangement of blowing equipment and gas-cleaning plant to suit all conditions, so that only an attempt to assess the relative merits of each can be made pending further consideration (p. 342).

(16) With mixer-type ladles the length of the hot-metal route is not a criterion, apart from limiting the energy expended in transit, but the route should be segregated from other routes. As the operation of pig casting does not require to be closely connected

with blast-furnace operation, the pig-casting equipment should preferably be kept clear of the blast-furnace plant. To facilitate the diversion, as dictated by production requirements, of hot metal from the melting shop to the pig-casting machine, it may be advisable for these two units to be closely situated (p. 343).

(17) The correct method of disposal of blast-furnace and melting-shop slag and of works rubbish and ashes, is largely an economic problem which requires to be solved locally. Evidence so far obtained is not conclusive in favour of any particular system of slag disposal and, in view of the considerable cost of slag handling in the industry, the subject might well merit further investigation (p. 343).

(18) The stripping, soaking-pit, and mould-preparation bays should be so arranged as to ensure complete flexibility between all three operations. Soaking pits should be reasonably close to the stripping bay to conserve heat in the ingots, whilst the desired flexibility may be attained by locating the three operations in separate buildings. On the other hand, with the possible sacrifice of some flexibility, the arrangement of these operations in one building would confer other advantages such as the ability to keep ingots flowing, in the event of a derailment, by the use of long-travelling cranes.

Junctions and cross-overs inside the bays should be avoided if at all possible, owing to the difficulty of preventing ingots from falling on the floor and the tendency to cause temporary congestion in the flow (p. 348).

(19) Storage of some ingots can usefully be arranged in the soaking-pit bays. Storage areas for cold ingots should be specifically allowed for, but need not be closely defined (p. 348).

(20) Soaking-pit bays, cogging- or slabbing-mill bays, and roughing- and finishing-mill bays, should preferably be arranged to provide a forward flow from ingot to finished product. As a railway system is not employed there is no reason why the cogging or slabbing mill should not be set at any desired angle to the soaking pits (p. 348).

(21) In this paper the authors are not concerned with the detailed layout of rolling mills, but only with the way in which the tracks emerge from the mills and connect with the works railway system. For this reason it is of interest to note that the loading tracks should preferably extend longitudinally, *i.e.*, in line with, or parallel to, the general forward flow through the mills from ingot to finished product, thus making the dispatch of finished product a continuation of this forward flow (p. 348).

(22) The 'pattern' of the railway system determines the features of the layout so that the works must be *built round the railway system*. Loops at both ends of the sidings are desirable, but in certain cases dead-end sidings are preferable to avoid traffic encroaching from the further end.

Space should be available for increasing where necessary the number of sidings to accommodate irregular volumes of traffic. Holding-sidings should be as close as possible to their respective departments and, as far as possible, should permit a gravity feed.

Outgoing sidings should be sufficiently large to enable the various types of wagon to be selected and marshalled as required by the range of products. Rising gradients should in general be avoided; where used they should be 'compensated' by arranging lower gradients on curves than on straights so that the tractive effort required is reasonably constant over the whole length of the gradient.

Diamond crossings should not be used in such a way that main-line traffic crosses. Bends in sidings should preferably be not less than 340 ft. in radius, and for hot-metal and 'through' tracks, not less than 600 ft. in radius. 'Blind' corners should be avoided (p. 349).

(23) A complete road system, arranged to suit the railway system, should be provided to give access to all units (p. 352).

(24) Although the authors have expressed an opinion concerning which of the tentative layouts reviewed are likely to be the most efficient, it is not practicable to assert which are necessarily the best to recommend until their relative merits, solely from the point of view of traffic handling, have been assessed (p. 354).

(25) Conditions in existing works, described in Tables I to XII, have mostly become unfavourable as a result of changes in process and rate of throughput.

(26) The results of this survey show that numerous aspects require detailed quantitative analysis and that each of these aspects is, individually, sufficiently large and important to form the subject of a separate investigation. The most important of these is a traffic survey of representative works (p. 354).

Acknowledgments

The authors would like to express their appreciation to all those companies who have granted them the necessary facilities to visit the works on which this paper is based, and for the cordial assistance afforded by works managements and executives in discussing the problems involved.

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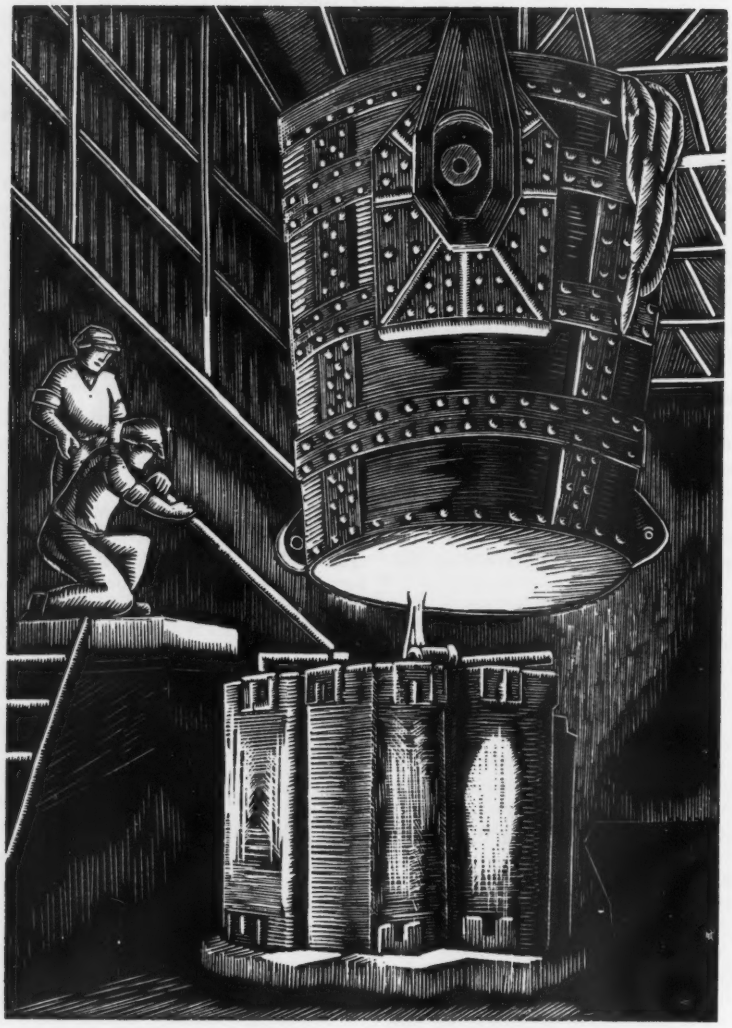
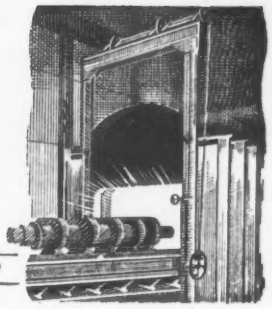


Bottom-pouring steel ingots—
from the original woodcut by Viva Talbot

IRON AND STEELWORKS ENGINEERING



THE IRON AND STEEL ENGINEERS GROUP

THE IRON AND STEEL ENGINEERS GROUP

REPORT OF THE EIGHTH MEETING

THE EIGHTH MEETING OF THE IRON AND STEEL ENGINEERS GROUP of The Iron and Steel Institute was held at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, on Wednesday, 24th November, 1948. Mr. W. F. CARTWRIGHT (The Steel Company of Wales, Ltd., Port Talbot), Chairman of the Group, occupied the Chair.

THE MORNING SESSION was devoted to the presentation and discussion of a paper on "Specialized Rolling Stock for Iron and Steel Works," by D. R. BROWN and T. H. STAYMAN, and to the presentation of a paper entitled "Ore Discharging," by G. T. SHOOSMITH. The proceedings of the Morning Session will be printed in a later issue of the *Journal*.

THE AFTERNOON SESSION was occupied by the discussion of Mr. Shoosmith's paper and by the presentation and discussion of a paper on "Belt Conveyors, Bunkers, and Chutes for Iron and Steel Works," by J. BRIMELOW. The discussion of Mr. Shoosmith's paper will be printed with the proceedings of the Morning Session, and the report of the discussion on Mr. Brimelow's paper is given below.

PROCEEDINGS OF THE AFTERNOON SESSION: 2 P.M. to 4.30 P.M.

Discussion on

BELT CONVEYORS, BUNKERS, AND CHUTES FOR IRON AND STEEL WORKS*

by J. Brimelow

Mr. **Brimelow** briefly presented his paper.

The **Chairman**: This paper covers a very wide field. Some people in steelworks are apt to take belt conveyors too much for granted, particularly if they do not suffer from the sticky material which the author has mentioned. The author's opening remarks about the scientific construction and weave of the belt must represent the first that many of us have heard about the matter.

Mr. **W. A. Johnson** (The United Steel Companies, Ltd.): I believe that there are those who feel that more use should be made of belt conveyors in steelworks for handling and moving material, and it is probably also true that there are those in ironworks who would like to be able to get on with less.

The author implies in his paper that with increased lengths of belts and greater driving powers, there is a tendency for them to become thicker. Is that necessary? I believe that in America, steel is incorporated in road vehicle tyres, and recently I saw an illustration of aeroplane landing gear which consisted of a belt landing track rather than wheels, with some steel wire woven into it.

The author in his presentation envisaged the possible use of rayon instead of cotton. I have no knowledge of their relative tensile strengths, but this is a step in the same direction. Multi-stranded steel cable of small overall diameter might very well be developed as a longitudinal strand in a rubber system, or narrow fine-gauge steel strip might serve the same purpose. I suppose that the former would be spliced in the same way that the author indicates that the best cotton duck belts are spliced, and then vulcanized in position, while the strips might be spot-welded before the jointing region was vulcanized and sealed-up.

Has the author any comments to make on that, and does he know if anything is being done in that direction. It seems to me that there is in this a possibility of real interest to iron and steel producers, in the first place because they use belts, and secondly because they make steel.

Mr. **W. C. E. Bell** (Messrs. Dorman, Long and Co., Ltd.): The author has made no reference to the use of hammock belts. I should like to have his opinion on the use of this type of belt.

Recently I visited two ore preparation plants of approximately the same capacity. At the first plant,

* *Journal of The Iron and Steel Institute*, 1948, vol. 160, Oct., pp. 185–196.

installed some twelve years ago, the original layout had five steel-roll-type troughing idlers fitted at the heavy-duty loading points, and these gave exceptional trouble, due to breaking of the idler components, and seriously damaged the belt. These difficulties were overcome by removing the three centre rollers of the installed idlers and introducing hammock belts instead, with the result that maintenance problems were greatly reduced and the life of the main belt was increased from four to eighteen months.

The second plant had a hammock belt with similar idlers fitted at the loading points, but owing to troubles experienced during trials the belts were removed, and in lieu of the steel idlers it is now proposed to instal rubber-covered idlers as being the most satisfactory method to withstand the impact at these points.

On page 189 of the paper, the author states that when a belt is fed on a slope it cannot take such a full load as when fed on the level, and it is a good rule to diminish the normal rated capacity of the belt by 1⅔% for every degree of slope. Is this carried out in practice?

On page 188 the author states that the manufacturers usually have two ranges of idlers, one for light or medium-weight materials and another for heavy ores or other heavy materials. Presumably a plant handling medium-weight materials will have medium-type anti-friction bearings, and heavy-type anti-friction bearings where heavy-type idlers are fitted.

On page 194 reference is made to the varying of the pitches of troughing idlers. Is this carried out in practice?

The first of the two plants previously mentioned started up with steel-tube idlers, but the rubber-disc type were later found to be the most suitable for handling sticky ore. In the second plant, however, steel-tube idlers have again been fitted. I would appreciate the author's comments on this.

Mr. **G. W. Lake** (Shelton Iron, Steel and Coal Co., Ltd.): It seems to me that the formulae which Mr. Brimelow gives for the horse-power required for conveyor belts are applicable only under certain conditions. The unloaded-belt horse-power is given separately, and for two belts which have recently been installed for conveying iron ore, the formula gives 0·8 h.p. and 2·0 h.p. respectively, whereas the actual power seems, on the basis of a rough estimate, to be 5 to 10 times as much. If the author could explain the discrepancy I should be very pleased.

Mr. **E. F. Woolridge** (The United Steel Companies, Ltd.): In iron and steel works practice it is often necessary to do a considerable amount of blending of materials, and this usually involves either discharging or loading at intermediate points along the length of a conveyor belt. I should like to have heard more about the means which are available for this purpose, although this may have involved excluding other interesting material.

In cases where conveyor belts are required to discharge at a number of points, the use of fixed or travelling trippers appears to be the most effective method. Although these are generally satisfactory, they have certain disadvantages, one of which is the increased tension caused by the belt being lifted clear of the idlers as it approaches the discharge pulley. A more simple method of discharging is provided by the use of a plough, but this is applicable only to flat belts and often causes excessive wear.

For the loading of belts, several different types of feeders are available. It would be interesting to know whether the author considers that the more expensive methods of loading give a reduction in maintenance costs, so far as the belt itself is concerned, as compared with the use of a chute. The author states that most of the wear takes place at the loading point, and presumably that is a reference to loading by means of a chute.

The reduction in the carrying capacity of an inclined belt is quoted as 1⅔% per degree of slope. Does that apply to a belt which is loaded at a point prior to the incline, or is the reduction somewhat less in that case?

Mr. **F. C. Doherty** (Messrs. Stewarts and Lloyds, Ltd., Corby, Northants.): At Corby, trouble has been experienced in conveying hot sinter on rubber belts. Can Mr. Brimelow say whether attention is being directed by belt manufacturers towards improving the heat-resisting qualities of special-purpose belts?

The **Chairman**: I should like to ask whether any effective scraper has yet been designed for taking off wet and sticky material at the end of the belt before it goes on its return journey, and also for the wet and sticky material which always sticks to the return idlers, or is it considered that the discs obviate the need to fit scrapers?

There have been many references to trippers, ploughs, etc. What is there to be said against the simple shuttle belt, which can be arranged to feed into any number of points with no trouble, and which has no expensive tensioning gear or other method of wearing the belt out, and which appears, from our experience, to be practically foolproof?

CORRESPONDENCE

Mr. **G. W. Lake** (Shelton Iron, Steel and Coal Co., Ltd.), further to his spoken contribution, wrote: Tests were carried out to obtain some accurate figures for the power required for conveyor belts. It was found somewhat difficult to arrive at an accurate figure for the horse-power taken by the unloaded belts on account of the steepness of the part of the motor efficiency curve concerned, but there does not seem to be any doubt that it is considerably more than that given by Mr. Brimelow's formula. With the loaded belts, however, no such doubt arises, and one belt takes about 50% more power than is indicated by the formula. The difference in the case of the other belt is not so great, but its length is less and its rise is greater. If the formula horse-power for conveying without lift is compared with the actual horse-power minus the theoretical horse-power for raising the material, it appears that the results given by the two belts are comparable. Details of the tests, which were carried out on two 36-in. 6-ply conveyor belts, recently installed for conveying iron ore and provided with five-roller ball-bearing troughing idlers, are as follows:

	Inclined Belt	Horizontal Belt with Travelling Tripper
Belt Data		
Length between centres, ft.	114	232
Head drum dia., in.	30	30
Tail drum dia., in.	24	24
Height material lifted, ft.	34¼	21¾
Slope of belt	18°	
Speed of belt, ft./min.	190	230
Motor power, h.p.	20	20
Motor speed, r.p.m.	720	720
Motor type	Slip ring	Slip ring
Reduction gear (worm) ratio	29·5 : 1	24·5 : 1
Loaded Belt		
Type of iron ore	Wabana	Wabana
Rate of conveying, tons/hr.	236	236
Power input to motor, kW.	13·2	14·4
Motor efficiency (from makers), %	87·2	87·7
Motor output, h.p.	15·4	16·9
Gear efficiency (estimated), %	87	89
Power required for belt, h.p.	13·4	15·1

	Inclined Belt	Horizontal Belt with Travelling Tripper
Unloaded Belt		
Material conveyed	Nil	Nil
Power input to motor, kW.	4·0	6·25
Motor efficiency (estimated), %	63	80
Motor output, h.p.	3·4	6·7
Power required by belt, h.p.	2·95	5·95
Calculations		
Power requirements calculated by Mr. Brimelow's formulae:		
(*a*) Unloaded belt, h.p.	0·81	2·0
(*b*) Conveying material, h.p.	0·74	1·51
(*c*) Lift, h.p.	9·2	5·80
	10·75	9·31
Length factor $\left(1 + \frac{20}{L}\right)$:	1·175	1·086
Total:	12·62	10·12
Factor for unloaded belt: Actual h.p. / Formula h.p.	3·1	2·7
Factor for loaded belt: (Actual h.p. − theoretical lift h.p.) / Formula h.p. (excluding lift)	2·3	2·4

The formulae may be suitable for certain conditions, but it does not seem that they can be used for belt conveyors handling materials such as iron ore. Belt scrapers are, of course, necessary on most belts, but possibly an additional allowance should be made when the material conveyed contains sticky particles as in the case of iron ore. It appears that about three times the power given by Mr. Brimelow's formulae (i) and (ii) should be taken for most steelworks conditions, and adequate allowance should be made for the loss in the reduction gears. It is also perhaps worth emphasizing the point, mentioned by Mr. Brimelow, that a conveyor belt drive should be calculated for the maximum, and not the nominal, rate for conveying; even with a feeder to deliver the material on to the belt, considerable variations in rate can take place with variations in the source and grading of the material. An under-powered drive can be very troublesome.

It may be claimed that the belts tested were taking more power than they should. They are, however, of very recent construction and are considered to be in quite good condition.

AUTHOR'S REPLY

Mr. **Brimelow** wrote: In reply to Mr. Johnson, the necessary thickness of belt depends largely upon the tension it has to carry, which may be very considerable. With the early type of idler, the thickness of the belt was limited so as to ensure good contact with the idler, but with modern idlers thicker belts are possible. Large pulleys are necessary for thick belts, and hard, *i.e.*, closely woven, belts are generally used with skim coats between the plies. Some heavily stressed belts have been made with ducks up to 48 oz.

In the early days of belt conveyors it was thought that the strength of the cotton duck would not be sufficient for the purpose, and many experiments were made in order to combine the strength of steel, in the form of wire or meshing, with the protective canvas and rubber covering. In practice, however, it has been found that the modern cotton duck belt with rubber cover will stand up to the duty, and this, coupled with the fact that it has been found difficult to make a really reliable composite belt, is the reason for the lack of development of the steel and rubber belt.

Rayon has been and is being used in the manufacture of belts; it has a greater tensile strength than the cotton duck, and for a given tension, a lighter and thinner belt can be used, with the added advantage of smaller pulleys. In a curved stretch of the conveyor, or if a travelling tripper is used, lightness in the belt may be a disadvantage.

Mr. Bell has asked for an opinion on the use of hammock belts. These are intended for use at the loading points of heavy-duty belts to prevent severe damage to the belt from the pounding of large and heavy pieces being fed to it. While I have had no first-hand experience with this device, I have been able to discuss the problem with others. The disadvantage of the arrangement, apart from the cost, is the difficulty of maintaining the central running of the hammock belt. The required result can generally be attained much more cheaply and with greater certainty, by a number of special rubber-covered troughing idlers spaced closely at the loading point, which does not call for the close attention that the hammock belt requires for continuous satisfactory performance. In such cases there should be some cushioning at the loading point in order to lessen the effect of the impact of heavy lumps on the surface of the main carrying belt. Rubber-covered idlers, with a layer of rubber, say, $\frac{3}{4}$ in. thick, provide the necessary resilience; the hammock belt is intended to supply this safeguard in a different manner.

Material loaded on to a belt on the slope usually takes a longer time to settle down than on a level belt. At the same time, the true cross-section of the material on the belt is less than when the belt is level, and account should be taken of this fact if a belt is to be fully loaded on the slope. This matter is often of small moment, as, for instance, where the size of lump dictates the width of belt, but in certain cases it is of importance, and it may be desirable to reduce the slope as much as possible by the introduction of a curve in order to ensure better loading.

Manufacturers can generally provide two ranges of idlers, one for use with light materials and duties, and a heavier pattern for more arduous work with heavy materials, the heavier range usually having larger pulleys and a heavier type of bearing.

The pitching of the idlers is coming into practice, particularly where the length of the belt and the driving tension are such that it is advantageous and convenient. With short belts, a close pitching at the feed point, where excessive sag in the belt may lead to damage, is usually adopted.

Mr. Lake has questioned the formulae for horse-power given in the paper. These are intended for use under average conditions and agree generally with the many different relationships used by various suppliers. In certain cases it may be desirable to check the accuracy of the assumption made, *viz.*, that the weight of the moving parts—belt and rotating parts of idlers, etc.—is $(1\frac{2}{3}\ W - 10)$ lb./ft.; in the design of belts of considerable length the actual figures should be obtained.

A scraper at the head pulley should make no appreciable difference to the horse-power, but if there are a number of them a suitable allowance should be made. This does not refer to the rotating type of brush scraper which, when driven from the head pulley, will require extra power.

Mr. Lake's suggestion that the coefficients in the formulae should be trebled is based on the results of one test made on each of two conveyors of the same width and of moderate length. It would appear, how-

ever, that many tests on belts of different widths, lengths, and speeds, should be made before any definite figure can be given.

Although in agreement with Mr. Lake that an under-powered belt drive is troublesome, the author must point out that one which is excessively over-powered is undesirable, and unless special precautions are taken in the control gear, the belt may be called upon to take very severe accelerating stresses.

Mr. Wooldridge refers to the usual methods of discharging and loading at the intermediate points along the conveyor length. Generally, loading is by means of a chute with or without a feeder, from a hopper which may, if desired, be arranged to travel along the conveyor and be loaded by any suitable means. For intermediate discharge, either fixed or travelling trippers, or, in some cases, ploughs, may be used. The disadvantage of the tripper lies not so much in the power required for the extra lifting material, as in the additional flexing caused in the belt when passing round the tripper pulleys. Thus a travelling tripper is preferable to a series of fixed trippers. Ploughs can be arranged with troughed belts in certain cases, and if the material is non-abrasive the belt will give good service. With this type of work the question is one of performance at minimum cost per ton, and if this is satisfactory, the comparatively short belt life is relatively unimportant.

With regard to the loading of belts, a chute, with or without a feeder, is nearly always used, and thus, in so far as wear on the belt is concerned, the feeder makes little difference. The advantage of the feeder is that it ensures that the belt will at no time be overloaded, and thus a belt-width no greater than necessary may be used.

Referring to inclined belts, the difficulty is not so much one of carrying capacity as of the possibility of loading it to capacity. The smaller the slope at the loading point, the better it is for loading.

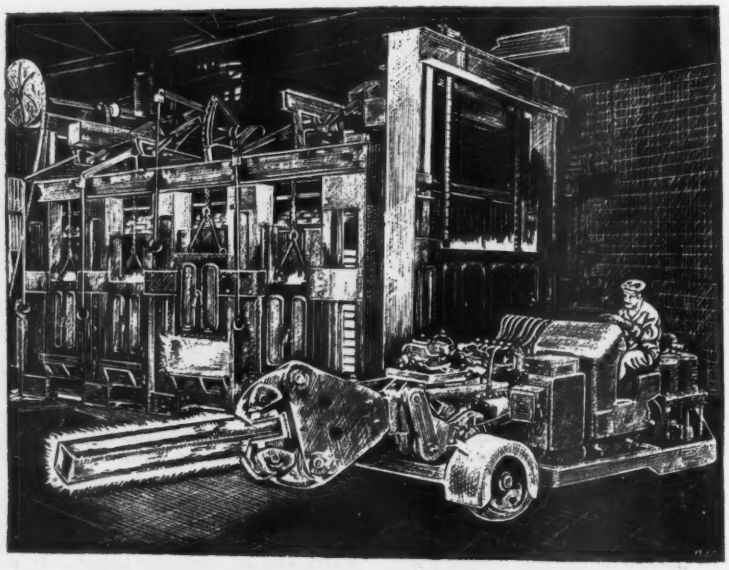
In reply to Mr. F. C. Doherty, who asks about the carrying of hot materials on rubber conveyor belts, manufacturers have produced compounds for use with hot material but, for a reasonable life, those at present produced are useful only for temperatures of about 250° F. A great deal depends upon the nature of the material being carried, which may be such that there is a certain amount of air cooling while on the belt. Fine materials prevent the access of cooling air and the belt quickly suffers. The heat dries out the frictioning compound in the carcase of the belt, and then the plies separate and the belt fails. Asbestos has been used under the rubber cover, but this has not proved satisfactory owing to the brittleness and shortness of the fibres.

The Chairman (Mr. W. F. Cartwright) has brought forward a very difficult matter with regard to the use of scrapers with wet and sticky materials. Probably the best method in difficult cases is to arrange a brush with a separate motor drive to clean the belt at a point just behind the drive pulley, or in place of the brush a rubber device may be used. Care must be taken to ensure the collection and removal of the fine material, and the apparatus must be under constant supervision so that wear may be taken up from time to time.

The fact that rubber scrapers need constant attention has led to the use of steel scrapers, which, however, are not ideal with belts jointed with metal fasteners.

With any arrangement, some material will at times pass on to the snub pulley and the return idlers. A scraper on the snub pulley will remove the greater part, but it has the disadvantage of being noisy. The building-up of material on the snub pulley and return idlers is likely to lead to damage owing to the belt running off-centre and having its edges damaged. This tendency is less with disc idlers than with the usual tubular return idler.

The shuttle belt referred to by Mr. Cartwright is a very convenient means for distributing the material from a feed conveyor to several points. It is more expensive than a tripper, and other things being the same, it requires somewhat greater headroom. It is very reliable and is mostly used in boiler houses and in similar services where a line of bunkers has to be filled from a single conveyor.



N E W S

ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1949

The Annual General Meeting of the Institute will be held on Wednesday, 27th April, 1949, in the Lecture Theatre, Central Hall, Westminster, London, S.W.1, and on Thursday, 28th April, 1949, at The Institution of Mechanical Engineers, Storey's Gate, London, S.W.1. The following is a detailed programme :

Wednesday, 27th April, 1949

9.45 a.m. to 1.30 p.m.—Morning Session, Lecture Theatre, Central Hall, Westminster

9.45 A.M. to 10.30 A.M.—
Official Business
Election of Members
Presentation of Report of Council, and Statement of Accounts for 1948
Resolution to Amend Bye-Laws Nos. 3, 21, 35, and 36
Presentation of the Bessemer Gold Medal for 1949
Presentation of the Sir Robert Hadfield Medal for 1949
Presentation of the Williams Prize for 1948
Presentation of the Ablett Prize for 1948.

10.30 A.M. to 11.30 A.M.—Discussion on :
"*The Conversion to Oil-Firing of the Open-Hearth Furnaces at Park Gate Works*," by D. F. Marshall and H. C. White (*April*, 1949)

11.30 A.M. to 12.30 P.M.—Discussion on :
"*An Electrical Pressure Meter for Measurement of Open-Hearth Furnace Differential Pressures*," by S. S. Carlisle and B. O. Smith (*March*, 1949)

12.30 P.M. to 1.15 P.M.—Discussion (time permitting) on :
"*First Report of the Gases and Non-Metallics Sub-Committee*," B.I.S.R.A., by W. W. Stevenson, G. E. Speight, R. M. Cook, and T. E. Rooney (*December*, 1948)

1.15 P.M. to 2.30 P.M.—Buffet Luncheon in the Library of the Central Hall, Westminster (tickets, price 6*s*. each, will be available at the Central Hall).

2.30 to 5 p.m. Afternoon Session

2.30 P.M. to 3.30 P.M.—Discussion on :
"*The Thermodynamics of Substances of Interest in Iron and Steel Making from 0° C. to 2400° C. 1—Oxides*," by F. D. Richardson and J. H. E. Jeffes (*November*, 1948)

3.30 P.M. to 4.30 P.M.—Joint Discussion on :
"*Large Crystal Grain Size in Silicon–Chromium Valve Steel*," by C. C. Hodgson and H. G. Baron (*February*, 1949)
"*Grain Growth in Silicon–Chromium Valve Steel*," by H. Allsop and P. W. Bygate (*April*, 1949)

4.30 P.M. to 5.0 P.M.—Discussion (time permitting) on :
"*The Structure of Carbides in Alloy Steels*," by H. J. Goldschmidt (*December*, 1948).

Thursday, 28th April, 1949

9.45 a.m. to 12.15 p.m.—Morning Session, The Institution of Mechanical Engineers, Storey's Gate, S.W.1

9.45 A.M. to 10.45 A.M.—Joint Discussion on :
"*The Charging of Open-Hearth Furnaces by Present Methods*," by E. L. Diamond and A. L. Frankau (*March*, 1949)
"*The Influence of Heat-Transfer on Open-Hearth Furnace Charging Rate*," by M. W. Thring (*March*, 1949)

10.45 A.M. to 11.45 A.M.—Discussion on :
"*The Layout of Integrated Iron and Steel Works*," by H. H. Mardon and J. S. Terrington (*April*, 1949)

11.45 A.M. to 12.15 P.M.—Discussion (time permitting) on :
"*The Application of Dry-Coke Cooling Plants to Integrated Iron and Steel Works*," by L. H. W. Savage and A. V. Brancker (*February*, 1949)

12.45 P.M. for 1.15 P.M.—Members' Luncheon at the Dorchester Hotel, Park Lane, W.1.

Note—The issues of the *Journal* in which the papers appear are given in brackets.

Special Summer Meeting in Norway, 1949

Particulars and programme of the special summer meeting to be held in Norway, from 28th May to 7th June, 1949, were given in the February *Journal*, pp. 139–140.

Awards

Bessemer Gold Medal

The Bessemer Gold Medal for 1949 has been awarded to **Professor J. H. Andrew, D.Sc.**, of Sheffield University.

Sir Robert Hadfield Medal

The Sir Robert Hadfield Medal for 1949 has been awarded to **Mr. M. W. Thring, M.A.**, Head of the Physics Department of B.I.S.R.A.

Williams Prize

The Williams Prize for 1948 (£100) has been awarded to **Mr. J. S. Bryan**, of Messrs. John Lysaght's Scunthorpe Works, Ltd., for his paper entitled, "*Gaseous and Liquid Fuels in Iron and Steel Works*," of which he is joint author with **Mr. J. B. R. Brooke.** Mr. Brooke, owing to his position in the industry, was not eligible for receipt of the prize.

Ablett Prizes

Ablett prizes for 1948 (£50 each) have been awarded to **Mr. G. S. Martin**, of The Lanarkshire Steel Co., Ltd., Flemington, and **Mr. M. Y. Harvey**, of Messrs. Colvilles,

Ltd., Glengarnock, for their paper entitled, "*The Maintenance of Electrical Machinery in Iron and Steel Works.*"

NEWS OF MEMBERS

▶ Mr. G. W. ALLOTT, technical adviser to the managing director of Messrs. Newton Chambers and Co., Ltd., Thorncliffe, has retired after 49 years' service with the company. Mr. Allott entered the drawing office in 1900; in 1930 he was made general sales manager, and in that capacity has travelled extensively in this country and abroad. He is being retained by Messrs. Newton Chambers and Co. Ltd., as consultant.

G. W. Allott

Mr. Allott is a past-president of the East and West Riding's branch of the Ironfounders' National Federation; he is on the main committee of the British Chemical Plant Manufacturers' Association, and is a past chairman, and present member, of the Gasholder Section of the Society of British Gas Industries.

▶ Mr. N. BEZBORA has left Britain to join the National Bearing Co., Ltd., Jaipur (Rajputana), India.

▶ Mr. F. C. BRABY is to be the first chairman of the newly founded Hot Dip Galvanisers Association.

▶ Mr. G. T. CALLIS has resigned his position with Messrs. J. Stone and Co., Ltd., Charlton, London, S.E.7, to take up the position of chief metallurgist of the Manganese Bronze and Brass Co., Ltd., Birkenhead.

▶ Mr. G. CAMPBELL, metallurgist at Messrs. Plessy Co., Swindon, has been awarded a Mond Nickel Travelling Fellowship, for one year.

▶ Mr. S. C. CLIFFORD has left Messrs. Humber, Ltd., of Coventry, and joined Messrs. John Garrington and Sons, Ltd., on 1st March.

▶ Dr. C. H. DESCH, F.R.S., has been elected an Honorary Member of the Société des Ingénieurs Civils de France.

▶ Mr. G. B. FORSTER has graduated in metallurgy at Leeds University, and has joined the staff of the Directorate of Weapon Research, Shell Mex House, Strand, W.C.2.

▶ Mr. M. GÉVERS, former director of the works of Messrs. Société Anonyme John Cockrill, of Grivegnée, Belgium, has been made a director of the affiliated company "Ferblatel."

▶ Sir CHARLES GOODEVE and Mr. E. W. SENIOR have accepted invitations to serve on an Honorary Advisory Council of the Industrial Finishes Exhibition, to be held at Earls Court, London, from 31st August to 13th September, 1949.

▶ Mr. L. H. GRAINGER has left Messrs. Davy and United Roll Foundry, and has accepted a position as works chemist and metallurgist with Messrs. E. R. and F. Turner, Ltd., Ipswich.

▶ Dr. J. V. HARDING has left Philips Electrical Ltd., London, W.C.2, to take up a position with the International Meehanite Metal Co., Ltd., London, S.W.1.

▶ Mr. E. HOUBAER, former director of metallurgy of the Société Anonyme John Cockrill, of Seraing, Belgium, has been elected deputy administrator of the affiliated company, "Ferblatel."

▶ Mr. CLEMENT HULME, assistant blast furnace manager at the North Works of the Steel Company of Wales, Ltd., has been appointed assistant works manager of the Port Talbot and Margam Works of that company.

▶ Dr. IVOR JENKINS has been awarded the degree of D.Sc. by the University of Wales, for his work in the field of metallurgy. Dr. Jenkins has also been elected a Fellow of the Institution of Metallurgists.

▶ Mr. F. O. JONES has left University College, Swansea, to take up an appointment at the A.E.I. Research Laboratory, at Aldermaston, Berks.

▶ Mr. S. K. KEN has left the Skinningrove Iron Co., Ltd., at Saltburn-by-the-Sea, and is now assistant-in-charge of the Iron and Steel Control of the Government of India, Calcutta.

▶ Mr. M. C. LLOYD is now with The Weldless Steel Tube Co., Ltd., at Wednesfield, near Wolverhampton.

▶ Mr. R. MCKENZIE HADDEN has been transferred to the New Development Section of the Clydesdale Works, Mossend, near Glasgow.

▶ Mr. W. K. B. MARSHALL, for some years works metallurgist with the British Aluminium Co., Ltd., and in the past eight years chief metallurgist, and later chief development engineer, to the A.P.V. Co., Ltd., Wandsworth, has been appointed assistant director of research of the British Welding Research Association, as from 1st March, 1949.

▶ Dr. P. D. MERICA, vice-president of the International Nickel Company of Canada, Ltd., since 1936, and a director of that company, has been made executive vice-president.

▶ Mr. J. NAYSMITH has joined the metallurgical department of Messrs. Stewarts and Lloyds, Ltd., near Market Harborough, Leicester.

▶ Mr. C. H. SAMANS has resigned from the Research Laboratory of the American Optical Company, Coatbridge, Massachusetts, U.S.A., to become associate director of the Engineering Research Department of the Standard Oil Co. (Indiana), Chicago 80, Illinois, U.S.A.

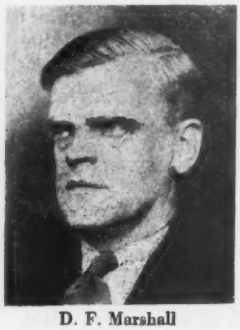
Obituary

Mr. ALGERNON LEWIS CURTIS, of Westmoor Works, Chatteris, Cambridgeshire, aged 67.

Mr. LEONARD SHAW DAVIS, director of Messrs. Edwin Danks (Oldbury) Ltd., and of Messrs. Penman and Co., Glasgow, on 11th November, 1948, aged 56.

CONTRIBUTORS TO THE JOURNAL

D. F. Marshall, B.Sc.(Tech.), Ph.D.—Fuel and refractories officer at The Park Gate Iron and Steel Company, Limited, Rotherham. Dr. Marshall was educated at the Central Secondary School, Sheffield, and at Sheffield University. After obtaining the degree of B.Sc.(Tech.) in 1930, he collaborated with the Midland Coke Research Committee in blast-furnace trials, the results of which were reported in two papers given to The Iron and Steel Institute in 1933. For one of these papers he was awarded a half-share in the Williams prize and a Carnegie Scholarship. He obtained the degree of Ph.D. in 1934; and was awarded the Carnegie Gold Medal in 1935,



D. F. Marshall

H. C. White

H. Allsop

P. W. Bygate

H. H. Mardon

G. R. Rigby

as a result of work published in a paper, "*Further Determination of the External Heat Loss of Blast Furnaces.*" In 1934 he was appointed to the staff of the Midland Coke Research Committee. Dr. Marshall has been engaged on problems relating to the operation of blast-furnaces, open-hearth furnaces, and mill-reheating furnaces, and is a member of several British Iron and Steel Research Association Committees dealing with these subjects. In this capacity he has presented papers to both the Blast-Furnace and Open-Hearth Conferences, and as a member of the Basic Furnace Linings Committee has contributed towards Special Reports Nos. 33 and 35. He took up his present post at the end of 1936.

H. C. White—Development Engineer at The Park Gate Iron and Steel Co., Ltd., Rotherham. Mr. White commenced as an engineering apprentice in the works of the Park Gate Company, and was later transferred to the drawing office. He received his technical education at the Rotherham Technical Institute, and Sheffield University. In 1940 he was appointed assistant chief draughtsman, and became chief draughtsman in 1945. He took up his present position in 1947.

H. Allsop, A.Met., F.I.M.—Chief of the laboratories of Messrs. Brown, Bayley's Steel Works, Ltd., Sheffield. Mr. Allsop was educated at Dronfield Grammar School. On leaving school in 1918, he entered the Brown-Firth Research Laboratories, and successively held appointments with Messrs. Samuel Fox and Co., Ltd., The Mond Nickel Co., Ltd. (research and development department), and joined Messrs. Brown, Bayley's Steel Works, Ltd., in 1931, as chief assistant in the laboratory. He was awarded the Associateship in Metallurgy at Sheffield University in 1923, and became a Fellow of the Institution of Metallurgists in 1946. Mr. Allsop took up his present position in 1935.

P. W. Bygate, A.Met.—Assistant metallurgist at Messrs. Brown, Bayley's Steel Works, Ltd., Sheffield. Mr. Bygate was educated at King Edward VII School, Sheffield. On leaving school, he entered the Laboratories of Messrs. Brown, Bayley's Steel Works, Ltd., where he is now an assistant metallurgist. He was awarded the Associateship in Metallurgy of Sheffield University in 1947. Mr. Bygate took up his present position in 1940.

H. H. Mardon, B.Sc.(Eng.), M.I.C.E., M.I.Mech.E., M.I.Struct.E., M.Am.S.C.E.—Head of the Plant Engineering Division of the British Iron and Steel Research Association. Mr. Mardon graduated with first-class honours, and obtained the Mechanical Engineering Prize at University College, London, in 1923. He was subsequently awarded the Gold Medal of the Chadwick Trust, and a Yarrow Scholarship of The Institution of Civil Engineers.

Mr. Mardon started his practical training with the late Sir Basil Mott, Bart., C.B., F.R.S., and has since gained a wide experience in the fields of civil and mechanical engineering. Between 1928 and 1942 he held administrative and executive appointments with Imperial Chemical Industries, Ltd., Dorman Long and Co., Ltd., The Anglo-Iranian Oil Co., Ltd., and The British Oxygen Co., Ltd. He joined the Ministry of Works in the earlier part of the war, and in 1945 he was appointed Chief Engineer of the Appleby-Frodingham Steel Co., when he was invited to become one of the original members of the Plant Engineering Panel of the British Iron and Steel Research Association. In the following year he was appointed Head of the Plant Engineering Division of the British Iron and Steel Research Association, where he is responsible for initiating and organizing engineering research. This has included investigations on steelworks' locomotives, open-hearth furnace charging, E.O.T. cranes, oil metering and burning, layout of works, traffic analysis, melting-shop design, mill furnaces, and dry cooling of coke.

Mr. Mardon has always taken an active interest in encouraging and promoting engineering research, and has, in the course of the past ten years, been invited to sit on committees of the Institute of Welding, The Iron and Steel Institute, and the Ministry of Fuel and Power.

J. S. Terrington, B.Sc. (Eng.) (Lond.), A.M.I.C.E., A.M.I. Struct.E.—Head of the Civil Engineering Section in the Plant Engineering Division of the British Iron and Steel Research Association. Mr. Terrington graduated with honours at the City and Guilds College of the Imperial College of Science, London, in 1925, and has since had a wide experience with consultants and contractors in the design and construction of civil engineering work. Mr. Terrington is the author of handbooks on the design of arch and other types of roof construction. He took up his present appointment with B.I.S.R.A. in August, 1946.

G. R. Rigby, B.Sc., Ph.D., D.I.C., A.R.C.S., A.R.I.C.—In charge of the refractory materials section of the British Ceramic Research Association, Stoke-on-Trent. Dr. Rigby is a native of Stoke-on-Trent, and studied chemistry at the North Staffordshire Technical College. In 1928 he was awarded a Royal Scholarship at the Imperial College of Science and Technology, London, where he obtained the B.Sc. degree, and the A.R.C.S. diploma, in chemistry (first-class honours). He gained the Ph.D. degree, and the D.I.C. diploma, for post-graduate research under Professor J. C. Phillip. In 1932 he was appointed to the staff of the British Refractories Research Association under the late Dr. J. W. Mellor. Mr. Rigby is the author of many papers presented to various technical societies, and published in The Iron and Steel Institute Special Reports, and in the Transactions of the

British Ceramic Society, and he is also the author of "*The Thin Section Mineralogy of Ceramic Materials*," published recently. In 1948 he received the Beilby Memorial Award of the Royal Institute of Chemistry, the Society of Chemical Industry, and the Institute of Metals, for his contributions to refractories technology.

IRON AND STEEL ENGINEERS GROUP

The Tenth Meeting of the Iron and Steel Engineers Group will be held at the offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, on Wednesday, 22nd June, 1949.

Three papers will be presented and discussed:

"*The Annealing of Mild-Steel Sheets and Coils*," by R. D. Pollard, H. Edwards, J. F. R. Jones, and J. Bromley Davis; a paper on pickling plant, by R. W. Treasure; a paper on the disposal of spent acid liquor, by W. B. Wragge.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Conference on Optical Techniques in Metallurgy

The British Iron and Steel Research Association is to hold a conference on 9th and 10th May, 1949, at Ashorne Hill, Leamington Spa. The general chairman will be Mr. E. W. Colbeck, of Messrs. Hadfields, Ltd.

The subject of discussion will be the practical application of the three techniques:—(1) phase contrast microscopy; (2) the multiple beam interference technique; (3) the reflecting microscope.

The first two of these techniques are in commercial use. The phase contrast microscope, already used to a large extent in biological work, with "transmission" technique, with the light shining through the specimen, is employed in metallurgical work with "reflection" technique. It is thought that this could be usefully employed for routine testing and in research.

The multiple beam interference technique, essentially a research tool for the study of surface topography, gives phenomenal magnification in depth, so that height changes of the order of 20 to 40 Ångstrom units may be estimated.

The reflecting microscope, not yet in use commercially, has the advantage of a large working distance, and can be used for examining specimens maintained under particular conditions, for example, at high temperatures. It has the further advantage that the instrument can be focused with visible light before using ultra-violet or infra-red rays.

Application to attend the conference and for accommodation at Ashorne Hill, should be made to the Metallurgy Division, the British Iron and Steel Research Association, 11 Park Lane, W.1.

Joint Panel of the Marine Corrosion Sub-Committee

At a little-reported meeting of The Iron and Steel Institute in 1946, it was disclosed that the Royal Navy had made extensive trials of an anti-corrosive paint formulation by the Marine Corrosion Sub-Committee of the British Iron and Steel Research Association.

Under the Chairmanship of Mr. F. Fancutt, of the Railway Executive (British Railways) the Panel, a Joint Technical Panel formed by the Marine Corrosion Sub-Committee in September 1946, has initiated tests of 68 special, formulated anti-corrosive compositions. Results are not yet available but the Interim Report (obtainable from the British Iron and Steel Research Association) reports progress up to the point where tests were actually applied.

THE INSTITUTE OF METALS

Award of Institute Medal for 1949

At the Annual General Meeting of the Institute, on Wednesday, 30th March, 1949, the President presented the Institute of Metals Medal (platinum) for 1949, to Dr. William Hume-Rothery, F.R.S., in recognition of his outstanding contributions to the science of non-ferrous metallurgy.

W. H. A. Robertson Medal and Premium

Messrs. W. H. A. Robertson and Company, Ltd., of Bedford, have offered to the Institute of Metals a medal and premium to be awarded for the encouragement of the publication of papers dealing with the engineering side of non-ferrous metal production. The Council of the Institute have gratefully accepted this offer, and designs for a medal, three inches in diameter, in bronze, have been approved.

The W. H. A. Robertson medal and premium will be awarded annually by the Council of the Institute, to the author or authors of the paper adjudged to be of the highest merit contributed to the *Journal of the Institute of Metals* on engineering aspects of non-ferrous metallurgy. No award will be made in any year when the Council is satisfied that no paper has been published which is of such merit as to justify the award.

For the first award, the Medal Committee of the Institute will consider papers published in the Institute's *Journal* from March 1948 to August 1949, inclusive. Thereafter the annual award will be made in respect of papers published in the *Journal of the Institute of Metals* covering the annual issues from September to August, inclusive.

Metallurgical Engineering Committee

The Council of the Institute of Metals has appointed a new standing Committee—the Metallurgical Engineering Committee—under the Chairmanship of Mr. D. F. Campbell, M.A., A.R.S.M., with the following terms of reference:

(*a*) To develop interest in metallurgical engineering in the non-ferrous metal industry, and to promote the study of equipment and instruments used in the industrial melting, casting, and working of non-ferrous materials.

(*b*) To make recommendations to the Council regarding the need for holding special meetings, discussions, and symposia; inviting papers or articles for publication; or the publication of books or other literature to attain the objects for which the Committee was formed.

(*c*) To make suggestions to the appropriate Committees of the Institute in connection with the organization of special meetings, or the production of publications approved by the Council on its recommendation.

Suspension of Entrance Fee

The Council of the Institute has resolved to suspend the entrance fee for membership, with effect from 1st January, 1949, for a period of two years, after which the matter will be reviewed.

CORRIGENDA

Dry-Coke Cooling Plant

"*The Application of Dry-Coke Cooling Plants to Integrated Iron and Steel Works*," by L. H. W. Savage and A. V. Brancker (*Journal of The Iron and Steel Institute*, 1949, vol. 161, Feb., p. 103): Page 108, Table III. The authors wish to emphasize that the capital costs given in Table III were appropriate for the year 1948

for new construction on a ' green field ' site, and did not include alterations and modifications which inevitably will be involved in the addition of a dry cooling plant to an existing coke-oven installation.

Historical Note No. 10

In the paper "*The Superiority of English Cast-Iron Cannon at the Close of the Sixteenth Century*," by H. R. Schubert (*Journal of The Iron and Steel Institute*, 1949, vol. 161, Feb., p. 85), the word "Barsberg," on p. 86, left-hand column, line 30, should read "Marsberg."

MEMOIRS

Charles Y. Clayton, B.Sc., Met. Eng., died on 27th June, 1948, in Rolla, Missouri, U.S.A., at the age of 57. From the Missouri School of Mines and Metallurgy he received, in 1913, the degree of Bachelor of Science in Metallurgical Engineering, and in 1916 the professional degree of Engineer of Mines. He was a Member of the American Institute of Mining and Metallurgy, the Mining and Metallurgical Society of America and the American Foundrymen's Association.

Mr. Clayton became a Member of The Iron and Steel Institute in 1919.

George Rudd Thompson, F.R.I.C., F.C.S., died on 3rd November, 1948, in his 81st year. Mr. Rudd Thompson was educated at Monmouth Grammar School, and entered University College, Cardiff, in 1883, as an Exhibitioner. In 1894 he was appointed District Analyst for Monmouthshire and the Borough of Newport, and in the following year was appointed Public Analyst. He was later appointed official Agricultural Analyst for both Councils. In 1908 he was elected a Fellow of the Institute of Chemistry, and was a Member of the Council of that Institute from 1921 to 1924. From 1924 to 1925 he was President of the Society of Public Analysts and other Analytical chemists.

Mr. Rudd Thompson was a member of the Chemical Society, and the Society of Chemical Industry. He became a member of The Iron and Steel Institute in 1946.

Leonard Shaw Davis died on 11th November, 1948, at the age of 56. Mr. Shaw Davis was born in Manchester. He came to London in 1929 and joined the staff of Messrs. Babcock and Wilcox, Ltd., in 1932. At the time of his death he was personal assistant to the Managing Director of Messrs. Babcock and Wilcox ; a director of Messrs. Edwin Danks (Oldbury) Ltd., and Messrs. Penman and Co., Glasgow ; President of the Mechanical Handling Engineers Association ; Chairman of the Tank and Industrial Plant Association, and a Council member of the British Engineers' Association. He was at one time a member of the Sutton and Cheam District Council, and at the time of his death was Chairman of the Sutton and Cheam Boy Scouts' Association.

Mr. Davies was on active service in the First World War, and in the Second World War he served in a voluntary capacity in the civil defence services of the Corporation of London, for which he was granted the Freedom of the City.

He became a Member of The Iron and Steel Institute in 1939.

Theodore Winthrop Robinson, B.S., died on 30th December, 1948. Mr. Robinson graduated from the Massachusetts Institute of Technology. He began his business career with the Joliet Steel Co., of Joliet, Illinois, U.S.A. On formation of the Illinois Steel Co., in 1889, he was put in charge of blast-furnace operation, and later became Vice-President and General Manager of that Company, which position he held until his retirement. He then became President, and later Chairman, of the Illinois Steel Co., Incorporated.

Mr. Robinson was a Member of the American Iron and Steel Institute, and of the Institute of Mining and Metallurgical Engineers. He was a Life Member of The Iron and Steel Institute, elected in 1891.

George Talbot Lunt died on 4th January, 1949, at the age of 60. Mr. Lunt was Managing Director of Bradley and Foster Ltd., Darlaston, and had been associated with the company for a period of over twenty-five years. He joined the Round Oak Works at the age of 18 years, and studied metallurgy at the Wednesbury Technical College, under Walter Macferlane, F.I.C. He was later in charge of the buying and costing departments at Earl Dudley's Round Oak Works. Mr. Lunt came to Darlaston in 1922, to take charge of the reconstruction and reorganization of the Bradley and Foster company, and its associated company, Thomas and Isaac Bradley, together with their various subsidiary activities. He joined the Board of Directors as General Manager and Secretary on the completion of the reorganization plans in 1926, becoming Managing Director and Secretary in 1931.

Under Mr. Lunt's direction the company installed a commercial heat-treating department, including the first nitrogen-hardening plant authorized for this treatment in the Midlands, in 1927 ; he introduced the manufacture of chilled metallic abrasives, metal powders, precast concrete, and the production of certain special-alloy-iron castings, including the high-silicon acid-resisting irons. During the Second World War the activities of this company extended, and the Ministry of Supply silicon iron factory, and the secondary hematite plant were established at Darlaston, under the management of Messrs. Bradley and Foster, and under Mr. Lunt's direction.

Mr. Lunt was Chairman and Managing Director of Arblaster and Co., Ltd., Wednesbury, and of the British Grit Corporation, he was a director of the Aberdeen Grit Co., Ltd., the Grit Company of Scotland Ltd., Grainger and Smith Ltd., Dudley, and Webley and Scott Ltd., Birmingham.

Mr. Lunt was actively associated with various organizations within the ironfounding and concrete industries. He was Chairman of the Cylinder and Refined Iron Association, Honorary Treasurer of the British Cast Iron Research Association, and was a member of the council and executive of the Joint Iron Council and its constituent councils, the C.F.A. and C.I.P. ; of the British Cast Concrete Federation ; of the Institute of British Foundrymen ; and of the Livery of the Worshipful Company of Founders. He was a Freeman of the City of London.

Mr. Lunt was elected a Member of The Iron and Steel Institute in 1928.

François de Wendel died on 12th January, 1949. Born on 5th May, 1874, in Paris, of a distinguished family of mining engineers, he gained the degree of Ingénieur Civil des Mines at l'École Nationale Supérieure des Mines de Paris, in 1889. He was associated with the coal mines Houillères de Petit-Rosselle, de Crespin, de Lievin, d'Orange-Nassau. At the first of these mines, prospected and opened up by his grandparents, he brought the production from 1,000,000 to 2,800,000 tons, and also further developed that magnificent city and social works started by the Maison de Wendel, a century earlier. Monsieur de Wendel was beloved by colleagues and employees. In 1903 he became a director of Les

Petit-Fils de François de Wendel, et Cie., and later became technical head of that firm, and also of La Société de Wendel, et Cie. During both world wars the works were seized by the Germans, and M. de Wendel organized their reconstruction when hostilities ceased. M. de Wendel was President of the Comité des Forges de France from 1918 to 1940; past Director of the Banque de France, and past member of the Chamber of Deputies of France. He was Senator of Meurthe-et-Moselle from 1932 to 1946. He became a Member of The Iron and Steel Institute in 1907.

Bernard W. Methley, F.R.I.C., F.I.M., died on 14th January, 1949, at Rotherham, at the age of 72. Mr. Methley was a native of Barnsley. After working with the City Analyst of Sheffield, and doing part time work at the old Firth College (now Sheffield University), he joined the Steel, Peech and Tozer branch of the United Steel Companies, Ltd., as chief assistant in the laboratory. He was soon appointed chief chemist, which appointment he held until he retired in 1947, when he became consultant to the United Steel Companies, Ltd.

Mr. Methley was past-President of the South Yorkshire and North Midland section of the Royal Institute of Chemistry, a Fellow of the Institution of Metallurgists, and a member of the Sheffield Metallurgical Association. He was elected a Member of The Iron and Steel Institute in 1946.

Mr. Methley was a keen golfer and yachtsman. He leaves a widow and one daughter.

DIARY

4th Apr.—INSTITUTE OF BRITISH FOUNDRYMEN (Sheffield Branch)—Annual Meeting. "*The Feeding of Steel Castings,*" by B. Gray—Royal Victoria Station Hotel, Sheffield, 7.30 P.M.

4th Apr.—CLEVELAND INSTITUTION OF ENGINEERS—"*Oil-Injection Method of Mounting and Dismantling Pressure Joints*"—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 P.M.

5th Apr.—PHYSICAL SOCIETY—33rd Exhibition—Annual exhibition of scientific instruments and apparatus—Physics Department, Imperial College of Science and Technology, South Kensington.

5th Apr.—SHEFFIELD METALLURGICAL ASSOCIATION—"*The Low Temperature Transformation of Austenite,*" by J. O. Ward—198 West Street, Sheffield, 1, 7 P.M.

6th Apr.—INSTITUTION OF WORKS MANAGERS (Leeds Branch)—"*Industrial Safety,*" by H. G. Winbolt—Great Northern Station Hotel, Leeds, 7.0 P.M.

7th Apr.—INSTITUTE OF METALS (London Local Section)—Annual General Meeting, 6.0 P.M. Open discussion on "*Controlled Atmospheres,*" introduced by I. Jenkins, 7.0 P.M.—4 Grosvenor Gardens, London, S.W.1.

7th Apr.—LEEDS METALLURGICAL SOCIETY—Film on rocket-flight development—Chemistry Department, Leeds University, 7.0 P.M.

7th Apr.—INSTITUTE OF METALS (Birmingham Local Section)—Annual General Meeting—James Watt Memorial Institute, Great Charles Street, Birmingham, 6.30 P.M.

7th Apr.—LIVERPOOL METALLURGICAL SOCIETY—Annual General Meeting—Films on "*Steelmaking,*" and "*A Story of Copper*"—9 The Temple, 24 Dale Street, Liverpool, 7.0 P.M.

7th Apr.—THE INSTITUTE OF PHYSICS (Midland Branch)—"*Physics in Steel Manufacture*"—Imperial Hotel, Birmingham, 6.30 P.M.

8th Apr.—SHEFFIELD METALLURGICAL ASSOCIATION (Refractories Group)—"*The Instrumentation of Open-Hearth Furnaces,*" by R. C. Baker—198 West Street, Sheffield, 1, 7.30 P.M.

9th Apr.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Film of the Ebbw Vale plant of Messrs. Richard Thomas and Baldwins, Ltd., introduced by P. M. Macnair—Lecture Room, Central Library, Alexandra Road, Swansea, 6.30 P.M.

12th Apr.—THE INSTITUTION OF MECHANICAL ENGINEERS (Automobile Division)—General Meeting in association with the Applied Mechanics Group—"*The Fatigue Strength of Cast Crankshafts,*" by R. J. Love and H. R. Mills, The Institution of Mechanical Engineers, Storey's Gate, S.W.1, 6 P.M.

12th Apr.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Chromatography,*" by G. R. Davies—198 West Street, Sheffield, 1, 7.0 P.M.

18th Apr.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Exhibition of Films—Royal Victoria Station Hotel, Sheffield, 6.15 P.M.

22nd Apr.—MIDLAND METALLURGICAL SOCIETIES (Joint meeting with the local section of the Royal Institute of Chemistry)—"*Corrosion,*" by W. H. J. Vernon—James Watt Institute, Great Charles Street, Birmingham, 6.30 P.M.

26th Apr.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Permanent Magnet Alloys,*" by K. Hoselitz—198 West Street, Sheffield, 1, 7.0 P.M.

5th May—LEEDS METALLURGICAL SOCIETY—Annual General Meeting and Students' papers—Chemistry Department, the University, Leeds—7.0 P.M.

6th–10th May—Summer Meeting Newcomen Society in Holland.

TRANSLATION SERVICE

(The previous announcement was made in the March, 1949, issue of the *Journal*, p. 252.)

TRANSLATIONS AVAILABLE

No. 375 (Italian) G. MALQUORI and V. CIRILLI: "Study of the Equilibria of Reduction of Calcium Ferrites and Brownmillerite with Carbon Monoxide." (*Gazzetta Chimica Italiana*, 1945, vol. 75, Aug.–Sep., pp. 137–156).

No. 376 (Swedish) S. BERGH: "The Influence of Small Contents of Lead on the Hot-Workability of Austenitic Stainless Steels." (*Jernkontorets Annaler*, 1948, vol. 132, No. 6, pp. 213–220).

PAPER ACCEPTED FOR TRANSLATION SINCE THE LAST ANNNOUNCEMENT.

(Russian) S. I. MASALOV: "The Production of Cold-Drawn Wire of Triangular Cross-Section." (*Katshestvennaia Stal*, 1938, No. 2, pp. 45–46).

TRANSLATIONS PREPARED AT MEMBERS' REQUEST—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether the translation can be prepared for inclusion in the Series.

CHARGES FOR COPIES OF TRANSLATIONS—For the above translations a charge will be made of £1 for the first copy and 10s. for each additional copy of the same translation. Requests should be accompanied by a remittance. The above translations are not available on loan from the Joint Library.

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES

IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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MINERAL RESOURCES

Vanadium in Iron Ores Consumed by the British Iron and Steel Industry. T. Deans. (Bulletin of the Imperial Institute, 1948, vol. 46, No. I, pp. 104–110). The distribution of vanadium in English and imported iron ores is examined. Of the four Jurassic ironstones which now provide 95% of the domestic iron ore production the average vanadium content is in the 0·035–0·07% range. Cleveland ironstone has the highest content and vanadium/iron ratio. The Swedish magnetites contain about 0·1% of vanadium and are the principal foreign vanadium-bearing ores used. Data on the vanadium contents of pig irons and steelmaking slags at five leading basic steelworks are given.—R. A. R.

The Wanganui-Wangaehu Ironsands. J. Finch. (New Zealand Journal of Science and Technology, 1947, vol. 29, July, pp. 36–51). An examination of the coastal dune sands between Wanganui and Wangaehu Rivers indicated that they are very low in iron ore content. A detailed mineralogical analysis showed that the greater part of these sands is derived from Tertiary sediments and volcanic rocks in the upper reaches of the Wanganui River.

Labrador—North America's Newest Great Iron Ore Field. J. A. Retty. (Mining and Metallurgy, 1948, vol. 29, Sept., pp. 480–483). An account is given of the steps so far taken to develop and exploit the iron ore deposits of Labrador. J. C. R.

Sweden's Mining and Metal Industries. (Metal Bulletin, 1948, Dec. 21, pp. 1–27). This review of Sweden's metallurgical industries gives statistics of the production of ores and metals for the last few years, lists the important mines and the metal firms, and gives an account of the plant and operations of the Boliden Company.—R. A. R.

Technical Properties of Otanmäki Ore from an Exploitation Point of View. K. Järvinen. (Suomen Kemistilehti, 1948, vol. 21A, pp. 59–65 : Chemical Abstracts, 1948, vol 42, Nov. 10, col. 8126). Otanmäki ore contains 36·5% magnetite, 23% ilmenite, 1·25% iron pyrites, and 38% other minerals, with a chemical analysis showing 26·4% magnetite iron, 8·5% ilmenite iron, 7·3% titanium, 0·65% sulphur, 0·24% vanadium, and less than 0·01% phosphorus. Grinding of the ore to 65 mesh allows fairly satisfactory separation into magnetite concentrates containing small amounts of highly disseminated ilmenite, and ilmenite concentrates containing hematite. The magnetite showed Fe 67%, Ti 2·2%, V 0·53%, S 0·15%, P 0·002%, Mn 0·10%, and 2·89% other elements by chemical analysis, and Fe_3O_4 89%, $FeTiO_3$ 6·96%, V_2O_3 0·74%, FeS_2 0·28%, MnO 0·13%, and 2·89% other minerals in a mineral analysis.

The Siderite–Pyrite–Hematite Deposit "Stazic" near Slupia Nowa, Central Poland. H. Lögters. (Zeitschrift für praktische Geologie, 1944, vol. 52, pp. 83–94 : Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8118).

Hills of Hematite. R. Vaill. (Iron Age, 1948, vol. 162, Dec. 16, pp. 81–85; Dec. 23, pp. 64–68 ; Dec. 30, pp. 34–40). The first part of this article deals with the discovery and early exploitation of the Minas Gerais ore deposits of Brazil, and outlines present proposals for their exploitation. In the second, the author deals with the economic and political difficulties which have, up to the present, delayed their development : he claims that Brazil could export 12,000,000 tons of iron ore per year for 1000 years. The third part demands joint U.S.A.–Brazilian enterprise to overcome these difficulties and put the ores at the disposal of United States industry : the virtues of steel made from them at Volta Redonda are highly praised.—J. P. S.

Report on a Geologic Mission in Magdalena and Atlántico Departments, Colombia. E. Reymond. (Colombia, Serv. geol. nacl., Estud. geol. 1942, vol. 5, pp. 417–460 ; Chemical Abstracts, 1948, vol. 42, Nov. 10, cols. 8118–8119). Reports are given on the alluvial magnetite deposit of Espíritu Santo and the deposit of the Torrente del Cristo, Magdalena. The magnetite is of good quality, high in iron and low in titanium.

Exploration of the Iron Mineral Deposit of La Plata, Huila Department, Colombia. B. Alvarado and R. Sarmiento. (Columbia, Serv. geol. nacl., Estud. geol., 1942, vol. 6, pp. 89–96 : Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8118).

Exploration of the Iron Deposit of Rovira, Tolima, Colombia. B. Alvarado and R. Sarmiento. (Colombia, Serv. geol. nacl., Estud. geol., 1942, vol. 6, pp. 97–104 : Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8118)

The Espíritu Santo Iron Deposit, Sevilla, Magdalena Department, Colombia. V. Mutis. (Colombia, Serv. geol. nacl., Estud. geol., 1943, vol. 6, pp. 415–432 : Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8118).

ORES—MINING AND TREATMENT

Economic Crushing and Screening in the Preparation of Ore by Means of Modern Crushing Machines and Shakers. J. Kesper. (Archiv für Metallkunde, 1948, vol. 2, No. 6, pp. 187–192). Some modern crushers, vibrating tables, washers, and dewaterers for treating ores are described. R. A. R.

Recent Developments in Heavy-Density Separation. J. V. Beall. (Mining and Metallurgy, 1948, vol. 29, Sept., pp. 488–492) The essential steps in the heavy-media separation process and the apparatus used are described. Brief accounts

are given of some heavy-media separation plants installed in recent years.—J. C. R.

Fine-Screening Investigations. Part II. S. Mörtsell and P. V. Villner. (Jernkontorets Annaler, 1948, vol. 132, No. 11, pp. 459–466). [In Swedish]. In the present paper, which is a continuation of an earlier investigation (*see* Journ. I. and S.I., 1943, No. II, p. 179A) three different vibrating screens, each with an area of 0·5–0·7 sq. m., are compared, and it is shown that one is better than the other two as regards the quality of the results. If only the quantity passing through the cloth is taken into account, one of the other screens seems to be the best. It is not certain, however, that the results would be the same if the same screens with larger areas were tested. For passing through the cloth of about 0·20 mm. mesh a vibration of about 1 mm. seems to be most suitable. The choking effect of the load, however, makes it necessary to maintain a somewhat stronger vibration.

The dilution also has an important effect on the screening results. Increasing dilution gives increasing capacity of material passing through the cloth, but too much dilution and too high a load decreases the screening efficiency.—J. K.

The Beneficiation of Certain Chromite Ores of India. P. I. A. Narayanan. (Transactions of the Mining, Geological, and Metallurgical Institute of India, 1946, vol. 41, Apr., pp. 155–175). A report is presented of tests on the treatment of chromite ores by (1) separation of the clay matter from the sands, (2) tabling, and (3) magnetic separation.—R. A. R.

Sinterization. F. E. Noe. (Brazil, Ministério da Agricultura, Departamento Nacional da Produção Mineral, Laboratorio da Produção Mineral, 1946, Boletim No. 22; Chemical Abstracts, 1948, vol. 42, Oct. 20, col. 7683). This is a review of the sinter process as applied to iron and steel, with particular reference to Brazilian conditions. Details are given of five American sintering plants.

Hematite Milling Plant at Marampa, Sierra Leone. G. L. L. Stone. (G.E.C. Journal, 1948, vol. 15, July, pp. 104–122). An illustrated description is given of the new concentration plant which was put in commission in 1944 at Marampa, Sierra Leone, for concentrating pulverulent specular hematite ore.—R. A. R.

FUEL—PREPARATION, PROPERTIES, AND USES

Pre-Mixed Combustion for More Efficient Process Heating in Industry. E. J. Funk, jun. (Industrial Heating, 1948, vol. 15, Nov., pp. 1894–1906, 1916). The advantages of premixing combustion air and fuel gas are discussed with descriptions of safety devices to prevent backfires. Its particular advantages for the immersion heating of plating baths are dealt with and details are gives of some installations. R. A. R.

Investigation by Models of a System Involving Radiation, Fusion, and Gas Flow. M. W. Thring. (Research, 1949, vol. 2, Jan., pp. 36–42). Two examples are described of the use of models in the laboratory to study processes of combustion and heat transfer in industrial furnaces. One model corresponds to the small-scale study of diffusion-combustion luminous flames, the radiation peak of which shifts according to the relation between the ratio of the heat radiated to the heat input and the mixing length. The second corresponds to the small-scale study of the heating and melting by radiation from above of a pile of irregularly shaped solids which sink in their own melt; this simulated the melting of steel scrap in an open-hearth furnace, and the marked increase in time required to complete melting of solid pieces of wax below the surface of molten wax was noted, whilst stirring the bath gave complete melting in one-seventh of the time required for an unstirred system.—R. A. R.

The Determination of Flame Speeds in Gaseous Mixtures. S. Sherratt and J. W. Linnett. (Transactions of the Faraday Society, 1948, vol. 44, Aug., pp. 596–608). A method of taking shadow and direct photographs of the flame cones on a cylindrical burner burning a coal-gas/air mixture and a new procedure for using the cones on the shadow photographs to determine burning velocities are described. Certain conclusions regarding the form of the flame region are also made. The effect of temperature on the burning velocity of a coal-gas/air mixture was measured and the results are compared with those obtained by formula based on other properties of the combustible mixture.—R. A. R.

Combustion Control. H. Ziebolz. (Iron and Steel Engineer, 1948, vol. 25, Oct., pp. 67–71). The methods that can be used for the proportioning of air and oxygen in combustion processes and particularly steel-mill practice, are outlined. The technique is similar to that employed in multi-fuel applications.

Crucible Coking Test. B. G. Simek, F. Coufalik and J. Choura. (Communications of the Coal Institute (Prague), 1948, No. 4, pp. 7–40: [Abstract] Monthly Bulletin of the British Coal Utilisation Research Association, 1948, vol. 12, Oct., p. 383). The sample of coal contained in a platinum iridium crucible (with silica lid) is covered by a smaller, inverted crucible of the same material. In addition, the space between inner and outer crucible is filled with 0·5–1 mm. grains of silica previously ignited. Coals which tend to decrepitate when heated are first moistened with ethanol.

The Application of Dry-Coke Cooling Plants to Integrated Iron and Steel Works. L. H. W. Savage and A. V. Brancker. (Journal of The Iron and Steel Institute, 1949, vol. 161, Feb., pp. 103–117). The main points of difference between three types of dry-coke cooling plant (Sulzer bunker-type, Sulzer chamber-type, and the Collin) and their influence on the coke-oven operation are described. Costs of operation are analysed with particular reference to the bunker-type cooling plant. Cost estimates have been compiled for a series of conditions, but in such a form that adjustments in the rates of particular items can be made if appropriate. The influence of dry cooling on the size and quality of the coke, and the effect of the plant on the fuel and power balance of an integrated works are discussed.

The German Coking Industry. (British Intelligence Objectives Sub-Committee, 1949, Final Report No. 1680: H.M. Stationery Office). This Report contains information collected by four teams, three of which visited German firms designing and constructing coke-oven and by-product plants, batteries of coke ovens built by them, and makers of silica bricks; their reports take up the first 223 pages. The fourth team was concerned with German coal and coke research and related matters; the account of its work takes up 85 pages. The last section of the Report consists of 95 diagrams and illustrations.—R. A. R.

Some Observations on Coking Practice in Germany. F. H. Reed. (United States Bureau of Mines, 1948, Information Circular No. 7462). The first part of this report consists of translations of three papers by A. Thau entitled "Metallurgical Coke from Coal of Upper Silesia," "Metallurgical Coke from Noncoking Coals, with Special Reference to the Two-Step Carbonization Process," and "Experiences and Suggestions as to the Economy of Raw Materials for the Hydrogenation or Low-Temperature Carbonization of True Coal, as well as for the Metallurgical Working-Up of Small-Grained Iron Ores." The second part describes the slanting Didier coke ovens at the Karlsruhe gasworks which were described in F.I.A.T. Report No. 566 (*See* Journ. I. and S.I., 1947, vol. 155, Jan., p. 146).

In the process described in the second of Thau's papers coal up to 50 mm. in size is carbonized in a continuous vertical chamber oven at 550–600° C., and freed from its tar constituents. The semicoke is discharged, cooled, crushed, and mixed with 5–8% of coal-tar pitch and 10–15% of coking coal. The mixture is briquetted in a roller press and the briquettes are carbonized at 900–1000° C.—R. A. R.

The Production of Metallurgical Coke from Non-Coking Coals. (Coke and Gas, 1948, vol. 10, Nov., pp. 397–402). The Didier two-stage process of making metallurgical coke referred to in the previous abstract is described and its economic aspects are discussed. Coke produced from lignite briquettes was carbonized in intermittent chamber ovens at Bratislava gasworks and was sent to Yugoslavia for a trial in blast-furnaces.—R. A. R.

Oxidation and Preheating Systems of Coal Carbonisation. J. Roberts. (Coke and Gas, 1948, vol. 10, Nov., pp. 377–380). Descriptions are given of processes in which strongly coking coals are oxidized at 100° to 300° C. to reduce the swelling power before being carbonized in a low-temperature retort to produce coke. The Roberts, Wisner, Disco, and Koppers-Bruay processes are described.—R. A. R.

Duration of Distillation in Carbonization Furnaces. H. Cassan. (Chaleur et Industrie, 1948, vol. 29, Dec., pp. 292–298). Various factors which influence the distillation period in the carbonization of coals in coke ovens are analysed. J. C. R.

Largest Low-Temperature Carbonisation Plant in the World. (Coke and Gas, 1948, vol. 10, Nov., pp. 386–390). A description is given of the Disco low-temperature carbonization plant now being erected near Pittsburg, Pa., to produce 1000 tons of coke per day. The process is completely continuous in every stage, and the product consists of homogeneous balls of smokeless solid fuel which do not require briquetting. The coal is preheated in rectangular multi-tray roasters and then passes into inclined rotating steel kilns 9 ft. in dia. by 126 ft. long. There will be seven kilns and a conveyor will collect the product from all of them and pass it over a grizzly on to shaking conveyors.

The Performance of Coking Plants. B. Hofmeister, E. Hülsbruch, and W. Mantel. (Bergbau Archiv, 1947, vol. 7, pp. 80–95 : [Abstract] Centre de Documentation Sidérurgique, Bulletin Analytique, 1948, Aug.–Sept., p. 50). The yields of coke, tar, and benzene obtained by the Bauer (distillation) process and the Schrot (low-temperature carbonization) process are compared. The calorific value of the products and the influence of the composition of the coals treated on the yield are discussed.

Synthetic Ammonia from Coke-Oven Gas. (Coke and Gas, 1948, vol. 10, Nov., pp. 391–396). An illustrated description is given of the plant for making ammonium sulphate from coke-oven gas and sulphuric acid at the Flixborough works of Nitrogen Fertilisers, Ltd. The plant takes coke-oven gas from the Lysaght steelworks and returns residual gas to the same works.

REFRACTORY MATERIALS

Manufacture of Basic Refractory Brick. R. L. Demmerle, R. E. Birch, and D. B. Hendryx. (Industrial and Engineering Chemistry, 1948, vol. 40, Oct., pp. 1762–1772). After a brief review of the history of the manufacture of refractories in the United States, a detailed description is given of the large refractory brick plant of the Harbison-Walker Refractories Co., Baltimore.—R. A. R.

Pure Oxide Refractories Withstand High Temperatures. O. J. Whittemore, jun. (Materials and Methods, 1948, vol. 28, Dec., pp. 79–81). To meet the demand for materials to resist very high temperatures, special materials composed of a single refractory oxide have been developed. This paper presents and discusses the properties of alumina, magnesia, zirconia, beryllia, and thoria refractories.—R. A. R.

Applications of Super-Refractories Made from Electric Furnace Products. C. F. Geiger, A. A. Turner, and O. R. Stach. (Chemical Engineering Progress, 1948, vol. 44, Dec., pp. 933–936). The properties of bonded refractories made from silicon carbide, fused alumina, and synthetic electric-furnace mullite, and of electrically fused cast refractories are presented and discussed.—R. A. R.

Destruction of the Bottom of a Basic Open-Hearth Furnace. P. S. Mamykin. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 60, pp. 255–256 : Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8127). After operating for 706 heats, the magnesite-brick bottom of a 45-ton furnace was completely disintegrated. Chemical and petrographic analysis indicated 30–50% periclase and 40–50% brucite present. Conversion of periclase to brucite was attributed to the use of wet brick when the bottom was laid.

BLAST-FURNACE PRACTICE AND THE PRODUCTION OF PIG IRON

Determination of the Shape of Blast Furnaces. G. Danese. (Metallurgia Italiana, 1948, vol. 40, Mar.–Apr., pp. 54–70). The author considers various factors which influence the size and shape of blast-furnaces.

Industrial Pig Iron. The Work of the Blast Furnace. B. T. Balfour. (Compressed Air and Hydraulic Engineering, 1948, vol. 13, Jan., pp. 1–4). Notes are given on modern blast-furnace practice in England.

Catalytic Agents for the Reduction Process in Blast Furnaces. M. I. Korobova and N. I. Korobov. (Bulletin de l'Académie des Sciences, U.R.S.S., Classe des Sciences Techniques, 1946, pp. 567–577 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8737). Since hydrogen is more effective than carbon monoxide in reducing iron ore above 840° and thus acts as a catalyst, the addition of 2–9% steam to the blast was tried. During a test for 23 days in a Magnitogorsk furnace, the average production rate with steam added was 1455 tons per day as compared with 1135 tons on dry blast. The blast temperature was maintained at 750°–800° when steam was added. In a test for 12 days in a Kuznetsk furnace, the addition of steam increased production from 1000 to 1113 tons/day, the blast temperature ranging from 500 to 730°. Calculations indicated that the blast temperature should be increased 74° for each percentage of steam added to compensate for heat of dissociation ; this places a practical limit of 6% steam with a blast temperature of 1000°. The addition of steam widened the oxidizing zone in the furnace, aided in uniform operation and elimination of a hanging charge, decreased coke consumption, and lowered the temperature of top gases.

Relationship between Blast-Furnace Burden and Fuel Economy in Iron and Steel Works. H. Schumacher. (Revue de Métallurgie, Extraits, 1948, vol. 45, Oct., pp. 246–249). This is a French translation of an article which appeared in Stahl und Eisen, 1947, vol. 66–67, Nov. 1, pp. 375–379. (*See* Journ. I. and S.I., 1948, vol. 158, Mar., p. 396).—R. F. F.

The Design of Large-Scale Oxygen Plants. E. Karwat. (Stahl und Eisen, 1948, vol. 68, Dec. 2, pp. 453–465). In planning a large-scale oxygen plant for an iron and steel works it is necessary to determine the quantity and degree of purity which will be required. Data for guidance in these calculations for the use of oxygen in blast-furnaces, low-shaft furnaces, Bessemer converters, and open-hearth furnaces are presented. The energy requirements for separating the air components are discussed and given in tables and graphs with examples of costs ruling before 1939. It is shown that the oxygen enrichment of blast for blast-furnaces and converters does not increase the consumption of heat energy as compared with ordinary practice. The space requirements of oxygen plants are considered. Finally, costs of oxygen production are dealt with and examples are shown of the manner in which costs are affected by the purity of the oxygen and the nature of the power supply, *i.e.*, steam, electricity, and gas.—R. A. R.

PRODUCTION OF STEEL

From Iron Ore to Steel. (B.H.P. Review, 1948, vol. 25, Mar., pp. 1–6). Plant and operation at the Newcastle Steel Works (New South Wales) are described ; these include iron ore mining, coal mining, preparation, and coking, pig iron production in a battery of three blast-furnaces, of total capacity 1600 tons/week, electrostatic gas cleaning, open-hearth steelmaking, and rolling. The mills comprise a blooming mill, 28-in. rail mill, 18-in. continuous bar mill, plate mill, another 18-in. bar mill (not continuous), fishplate mill, 12-in. mill, 10-in. merchant strip and skelp mill, a rod mill, and cold strip mills.—M. A. V.

Metallurgical Treatment of Chips and Borings. E. R. Thews. (Canadian Metals and Metallurgical Industries, 1948, vol. 11, Oct., pp. 23–24, 30, 32, 35 ; Nov., pp. 24–30). Most of this paper is concerned with treating non-ferrous metal chips and borings, but it is stated that steel or iron chips can be converted into solid blocks for blast-furnace size by a simple process of fusion. A fire is started with wood, and steel turnings and chips are piled on top, the thinnest material being put on first. A fire can be kept going for 2 hr. in this way and it eventually burns out due to the accumulation of unburnable materials, principally iron oxide skeletons, within the pile ; a crude iron containing 85–88% of iron and 8–10% of iron oxide is produced.—R. A R.

American Steelworks Practice. A. Mund. (Stahl und Eisen, 1948, vol. 68, Dec. 2, pp. 465–478). American steelworks practice during and after the 1939–1945 war is reviewed, the information being based on the Open-Hearth Conferences of the American Institute of Mining and Metallurgical Engineers.—R. A. R.

Appleby-Frodingham. Open-Hearth Furnaces and Other Developments. (Iron and Steel, 1948, vol. 21, Dec., pp. 607–610). Illustrated descriptions are given of the plant at the Appleby melting shop and the new Frodingham (South) melting shop of the Appleby-Frodingham Steel Co., Ltd. J. C. R.

The Application of Slag Control to the Manufacture of Tube Steel. J. Monaghan. (West of Scotland Iron and Steel Institute, Dec. 17, 1948, Preprint). The system of slag control developed at the works of Stewarts and Lloyds Ltd., and applied to making tube steel is described. Slag assessment is by a combination of pancake examination, chemical

analysis for iron and lime, and a new rapid method for estimating the V-ratio of the slag ($V = CaO/(SiO_2 + P_2O_5)$) by conductivity measurements of slag water extracts (*see* Journ. I and S.I. 1948, vol. 160, Oct., p. 121). Calculations of feed lime and scale are rapidly carried out by graphical methods, taking into account dolomite erosion from the furnace banks and bottom, and the oxidation by the furnace atmosphere. The rate of feeding lime and scale is carefully controlled so as to have a vigorous carbon boil early in the heat, slowing down to a gentle boil at tapping. A method of calculating the bank erosions during the charge plus melt and the refining periods is used to obtain average values which are incorporated in the calculation of the lime additions. Slag control is practised on all steel made, but different specifications for tapping-slag V-ratio and iron content are used for each grade of steel, depending on the tapping carbon and the deoxidation. These specifications are based on an examination of the effects of slag basicity on the final phosphorus and the amount of phosphorus reversion at tapping.

The system has resulted in better control of sulphur and phosphorus in the final steel with concurrent improvements in yields and steel cleanliness.—R. A. R.

The Application of the Results of Some Steel Furnace Trials to Glass Furnace Practice. M. W. Thring. (Journal of the Society of Glass Technology, 1948, vol. 32, Aug., pp. 189–210). Furnace research can be judged by its effects upon the quality of the product, refractory life, output, and thermal efficiency of the furnace. While the emphasis in glass tank furnace research is somewhat different from that in steel furnaces a study of port design in the latter gave results which can be of interest in the former. Three furnaces of standard Venturi and Maerz design were compared by trials in which all the variables relevant to combustion were measured, a heat flow meter giving the direct measure of the flame radiation. It was concluded that: (1) Both in steel and glass furnaces the use of instruments to a considerably greater extent is probably the most important single line of improvement, particularly by the use of CO_2 or oxygen meters to control the excess air and air infiltration; and (2) flames are in general too long and ports giving better mixing are therefore desirable.

The Cinematography of Open-Hearth Furnace Flames. J. H. Chesters. (Journal of the Society of Glass Technology, 1948, vol. 32, Aug., pp. 209–210). A summary is given of a talk which was followed by the showing of a film of coloured flames passing through an open-hearth furnace. The cinematography technique is described. It was noted that the velocity of an oil flame is approximately four times that observed with producer gas.—R. A. R.

Production of Manganese Steel in the Basic Electric Furnace and Its Properties. J. Ramalho. (Boletim da Associação Brasileira de Metais, 1948, vol. 4, pp. 293–299).

The Role of Thermochemical Factors in Basic Open-Hearth Production Rate. T. E. Brower and B. M. Larsen. (American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2451 : Metals Technology, 1948, vol. 15, Oct.). The authors discuss various factors affecting the heat balance in basic open-hearth practice, and attempt to evaluate the net bath heat requirement and the extent to which it may change through variations in these factors. Results of investigations are presented in tables and graphs.—J. C. R.

Note on the Distribution of Sulphur between Molten Iron and Slag. T. Rosenqvist. (American Institute of Mining and Metallurgical Engineers, Technical Note No. 7 : Metals Technology, 1948, vol. 15, Oct.). After briefly reviewing the theories of other investigators, the author suggests the following formula for sulphur distribution between molten metal and slag:

$$S_{metal} + O^{2-}{}_{slag} \rightarrow S^{2-}{}_{slag} + O.$$

In order to determine whether the mechanism suggested by this equation is correct, experiments are being conducted where two of the four activities are kept absolutely constant.—J. C. R.

Investigations of Basic Open-Hearth Slags with the Metallurgical Microscope. H. Petterson and S. Eketorp. (Revue de Métallurgie, Extraits, 1948, vol. 45, Nov., pp. 295–298). This is an abridged translation into French of an article which appeared in Jernkontorets Annaler, 1946, vol. 130, No. 12, pp. 664–677. (*See* Journ. I. and S.I., 1947, vol. 156, May, p. 133).—R. F. F.

Functions of Slag in the Open-Hearth Process. R. Higgins. (Dryffryn Metallurgical Society: Iron and Coal Trades Review, 1949, vol. 158, Jan. 7, pp. 13–16). The author discusses the causes and methods of oxidation of the slag and the metal bath, and the functions of the slag during the refining period in open-hearth steelmaking practice.—J. C. R.

Calculation of the Composition of Oxidizing Slags in Electric Arc Furnaces. A. M. Samarin, A. Yu. Polyakov, and L. A. Shvartsman. (Bulletin de l'Académie des Sciences, U.R.S.S., Classe des Sciences Techniques, 1947, pp. 1639–1648: Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8089). Physicochemical methods are reviewed for calculating the composition of slags necessary for the oxidation of carbon.

Steel-Making by Electric Arc Furnace Process. T. V. Simkinson. (Canadian Metals and Metallurgical Processes, 1948, vol. 11, Nov., pp. 14–17, 30; Dec., pp. 14–17, 26–29). *See* Journ. I. and S.I., 1948, vol. 159, Aug., p. 436.

Production of Electric-Arc-Furnace Steel. Part II. W. M. Farnsworth. (Steel, 1948, vol. 123, Dec. 27, pp. 76–88). Continuation of a previous article (*see* I. and S.I., 1949, vol. 161, Mar., p. 256). The working of a charge, on the two-slag system, and the function of each slag, is described both for low alloy and for stainless steels. Charging and pouring practice are also outlined.—J. P. S.

New Arc Furnace for Electro-Metallurgical Researches. (Journal du Four Electrique, 1948, vol. 57, May–June, pp. 49–51). A 50-kW. arc furnace specially designed for use in research laboratories is described.

An Evaluation of Steel Cleanliness. P. Schane, jun. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 3–10). Having briefly touched on the detrimental effects and classification of inclusions, and methods of discovering their presence, their elimination from basic electric-furnace steel is discussed. A vigorous boil is advocated. If too much deoxidizer is added to the refining slag at one time some may enter the steel and react with iron oxide to form inclusions; the deoxidizer should be added frequently in small lots. To reduce the time the steel is in contact with the air, fast tapping in a solid stream and a protective covering of slag on the steel in the ladle are recommended.—R. A. R.

Deoxidation and Deoxidation Products in Electric-Furnace Steel. S. W. Poole. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 13–22). The relation between deoxidation practice and the type of inclusions found in the ingot is discussed, results obtained by Marsh and by Tenenbaum and Brown being quoted. Methods of studying inclusions are briefly examined. As to radio-active isotopes, it is unfortunate that silicon and aluminium, the two elements most frequently occurring in inclusions in fully deoxidized steel, have a serious limitation in that there is a long time lag before the artificially induced radio-activity of the atoms in the inclusion can be detected. An active boil and a high bath temperature are recommended to eliminate inclusions. The basic lime silicate slag used in the refining or deoxidizing period should contain more than 60% CaO and less than 0·50% FeO. Coke may be added to this slag to promote a reducing reaction.—R. A. R.

A Review of the Effects of Refractories on Cleanliness of Steel. J. G. Mravec. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 22–31). Experience of the Timken Roller Bearing Co., in the testing and identification of inclusions in steel is reported. No inclusions originating from the magnesite of the furnace banks and bottoms have been found; all have been of the fireclay type. Inclusions are found more frequently in low carbon steels than in medium and high carbon steels. Special quality refractory materials have been used in runners, ladles and nozzles, but, in general, they were not found to be more beneficial to steel cleanliness than conventional fireclay refractories. Control of pouring temperature is the most important single factor affecting steel cleanliness, for cold heats tend to be very dirty irrespective of the refractories used and the casting-pit practice.

R. A. R.

Problems Associated with the Production of Sound Ingots. R. L. Stephenson. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 32–42). The mechanism of segregation and the solidification of ingots are described

and discussed. The most difficulty occurs in the carbon content range of 0·18–0·23%. Excessively high pouring temperatures, pouring irregularities, some features of mould design, and a long period between completion of pouring and charging the soaking pit combine to cause unsound ingots. In some fluted moulds the steel contracts away from the bottom of the flutes and touches one side of a flute ; columnar crystals grow inwards more rapidly at such points of contact and the crystals on each side are stopped short where they meet the longer ones, thus causing a plane of weakness. An explanation of a fold with interdendritic segregation well below the surface is also given.

Large Ingots. F. B. Foley. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 43–49). Recommendations on the casting of very large ingots are made. An ingot weighing 448,800 lb. was made by bottom-pouring the first 7500 lb. through a runner to form a pool and reduce splash ; the remainder was poured from a head-box with a 2-in. nozzle, the ladle nozzle being 3 in. in dia. With such a mass of metal mechanical considerations govern the mould design and casting procedure. In the above case the mould was set small end up so that the mould could be stripped off the ingot. Some mould to ingot area ratios and weight ratios for large ingots are given. After the area ratio attains a value of about 1, any further increase in wall thickness has a negligible effect on the rate of solidification.—R. A. R.

Production of Sound Billet-Type Ingots. B. C. Blake. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 49–51). Pouring and stripping practice for making ingots with a length/thickness ratio of about 11 is described. The ingots are octagonal and range between $3\frac{7}{8} \times 3\frac{1}{4} \times 44$ in., and $5 \times 4 \times 60$ in. Nearly all the contraction is longitudinal and the sides remain in contact with the mould surface producing a silver-like unoxidized surface. The moulds must be vertical and the ladle nozzle directly above the centre. The nozzle must be opened and closed slowly : unusual care is taken with nozzle assembly and this ensures that one nozzle will last for the 200 openings required to cast 125-lb. ingots from one 12-ton heat. The staple is put in the top of the ingot as late as possible to reduce the chilling effect and prevent pipe formation.—R. A. R.

The Dornin Process. G. A. Dornin, jun. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 52–58). A description is given of the Dornin process for removing segregation from the top of ingots. Standard killed steel melting practice is employed, and the steel is poured into a big-end-up mould with a taper two to three times that normal for hot-top ingots. The ingot is stripped and soaked in the usual way. The processing is done under a press or presses. In the first stage a hollow tapered punch, large enough to surround the cavity, is driven into the top of the ingot to the bottom of the segregate, the bottom of the punch being protected with Stellite. An upsetting die is used in the second stage to drive the steel surrounding the segregate downwards and raise the segregate in the centre by displacement. If the raised core were now cropped off, the remainder of the ingot would be sound except for 1–2% representing the original top surface. The last step is to remove the ingot from the holding die and forge it to a size suitable for the blooming mill. The ingot is given a flash reheat between forging and rolling and the top is normally cropped after rolling. Allowing a total scale loss of 3–4%, a bottom crop of 2–3% and a top crop of 4–5%, a blooming-mill yield of about 90% is obtained. To ensure a shallow cavity in the ingot on solidification, cork is applied, immediately after pouring, to a depth of 2 in. at the outside and 4 in. in the middle. Transverse and longitudinal etches of ingots produced in this way are shown.—R. A. R.

Effect of Mold Thickness and Cooling on Base Quality of Intermediate Size Ingots. G. Breyer. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 59–66). The effect of pouring temperature, mould thickness and cooling rate on the quality of alloy steel ingots for tube making has been studied. The optimum pouring temperature was 2850° F. Some 20-in. ingots were cast in big-end-up moulds of twice the normal thickness and inclusion counts were made at various positions, no general improvement in quality was noted, nor was the depth of cavity reduced. To test the effect of accelerated cooling of the bottom of the ingot some were cast in Ahearn moulds which are raised on short legs to permit air to circulate round the base ; there was no noticeable improvement.—R. A. R.

Present Applications of Oxygen in Electric Furnace Steelmaking. J. H. Berryman. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 78–82). The use of oxygen in electric furnace practice for helping to melt the scrap, controlling temperature, and accelerating decarburization is described. Water-cooled nozzles for melting floating scrap with oxygen have been devised ; water from the electrode coolers is used and its temperature is raised by 30–40° F. only. A sluggish bath can be quickly activated by injecting a relatively small amount of oxygen ; temperature increases of 50° to 150° F. in blowing periods of 7 to 15 min. in a 45-ton heat of alloy steel are common practice. Oxygen injection is particularly useful for decarburizing low-carbon silicon steel heats and in making chromium steel. Charges high in chromium steel scrap can be dealt with and the removal of carbon is so rapid that much less chromic oxide forms in the slag than with scale and ore additions instead of oxygen ; the furnace walls and roof remain in better condition. Average savings of 20% in electricity consumption are obtained with oxygen-treated heats.—R. A. R.

Some Aspects of the Use of Oxygen in the Electric Furnaces. J. M. Gaines and G. M. Skinner. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 82–93). The equipment and technique for supplying oxygen to electric steel furnaces is described and discussed. After the electrodes have melted a hole down into the scrap and formed a pool at the bottom, the water-cooled oxygen jet is directed on to this pool and the solid scrap surrounding it. In a melting shop using oxygen to assist in melting the scrap, but not for decarburizing, a saving of about 3% in power consumption was noted. For decarburizing, the jet is held 3 to 6 in. above the bath surface ; dense clouds of brownish yellow fumes are given off in which yellow flames increase in volume as the rate of carbon removal increases with rising temperature. Average figures for six heats in a 9-ton furnace showed that 1820 cu. ft. of oxygen were equivalent to 1180 lb. of ore for lowering the carbon from 0·36% to 0·10%, and the saving in heat time was 46 min. Disadvantages in using oxygen include the large number of tubes used in the lance process, and the need for three flexible pipes across the floor with the water-cooled jet process.—R. A. R.

Problems in Supplying Scrap for Electric Furnace Requirements. S. M. Kaplin. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 94–97). The position regarding the supply of steel scrap in the United States is discussed. The need for separating alloy steel scrap from carbon steel scrap, and different kinds of alloy steel scrap from each other is stressed.—R. A. R.

The Outlook for Scrap. E. C. Barringer. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 97–104). The scrap market in the United States is reviewed. In nine months of 1947 the scrap industry collected, prepared and supplied 15 million tons of scrap. The Army is believed to have 15 million tons of ammunition in reserve, some of which is destined for scrap. Large quantities of scrap are known to be in Germany, but how much of it will come to the United States cannot be stated. Automobile graveyards form a large potential source of supply.

Buying scrap on the basis of weight per cubic foot was raised in the discussion and considered to be impracticable. R. A. R.

A Quantitative Experimental Investigation of the Hydrogen and Nitrogen Contents of Steel during Commercial Melting. C. E. Sims, G. A. Moore, and D. W. Williams. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 106–129). The paper is in two sections. In the first some of the literature on hydrogen and nitrogen in steel is reviewed (thirteen references), in the second the behaviour of 20 heats with respect to hydrogen and nitrogen contents

of the steel in the furnace and in the ladle is studied on the basis of many analyses during the heats and from the ladle. The nitrogen content fell rapidly after melt down and followed a line parallel with the carbon content line. In no case was sufficient nitrogen present to cause any changes in the physical properties of the steel. Data on the hydrogen contents are given in 'RV' (relative volumes) where one RV is the amount of hydrogen at 0° C. and atmospheric pressure which would occupy the same space as the amount of steel (free from porosity) analysed. The amount of hydrogen usually present in steel in the ladle is 0·30 RV or more, and sufficient of this will be retained in test bars and castings to cause an important reduction in ductility. The amount can be reduced by maintaining a strong boil (*i.e.*, one which reduces the carbon from 0·40% to 1·0% in 1 hr.). The acid arc furnace is most amenable and the basic open-hearth furnace least amenable to this control. To keep the hydrogen at a low level the duration of the inactive period after boiling must be strictly limited and ladles must be throughly dried. R. A. R.

A Rational Process for the Improved Manufacture of Steel without Inclusions. G. Ranque. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec. 4–6, 1947, Proceedings, vol. 5, pp. 130–150). This is an abridged English translation by S. Marshall of G. Ranque's paper which appeared in *Revue de Métallurgie*, 1942, vol. 39, Nov., pp. 331–344; Dec., pp. 360–369; 1943, vol. 40, Jan., pp. 25–29 (*see* Journ. I. and S.I., 1946, No. I, p. 4A).

High Frequency Induction Heating. Application of the Theory to Melting Furnaces. M. Renouard. (Revue Générale de l'Electricité, 1948, vol. 57, pp. 322–337: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8662). Principles and theory are explained. From applying the latter to industrial melting furnaces without a magnetic core, the author derives the conclusion that high-frequency furnaces will heat with good efficiency metals or alloys of high resistivity (especially when they are magnetic) but for metals of low sensitivity the efficiency is low. Furnaces for constant frequency are good for very special conditions only, *i.e.*, for a definite type of alloy; outside of these conditions the efficiency and production are lowered.

New Methods for Sampling Molten Steel. (Österreichischer Maschinenmarkt und Elektrowirtschaft, 1948, vol. 3, Oct., p. 326). The General Electric Co., Schenectady, has produced a sampling device which consists of a tube of heat-resisting glass with a rubber bulb at one end. Molten steel is drawn up the tube and allowed to solidify. The glass is broken off, leaving a bar with a clean polished surface; the bar is cut in two and the two parts are used as the electrodes in a spectrograph.—R. A. R.

PRODUCTION OF FERRO-ALLOYS

50 Years of Electric Furnace Production of Ferro-Alloys. (Journal du Four Electrique, 1948, vol. 57, May–June, pp. 46–48). The developments of electric furnace production of ferro-alloys during the last fifty years are surveyed.—R. F. F.

Phase Components and Chromium Losses in Cheliabinsk Slags from Fluxed Smelting of Low-Carbon Ferrochromium. D. S. Belyankin and V. V. Lapin. (Bulletin de l'Académie des Sciences, U.R.S.S., Classe des Sciences Techniques, 1946, pp. 561–566: Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8127). The chemical and mineralogical compounds of slags from low-carbon ferro-chromium heats (1) fluxed with lime and (2) smelted without fluxes, are compared. The slag from fluxed heats contained (1) residual chromium spinel from ore, (2) newly formed chromium spinel, (3) silicates of the type $2RO.SiO_2$, (4) gehlenite, and (5) metal shot. The newly formed chromium spinel from either non-fluxed or lime-fluxed heats contained less FeO, more MgO, and slightly more Cr_2O_3 than ore spinel. The newly formed spinel from non-fluxed heats contained less FeO than spinel from fluxed slags. Excluding metal shot, almost all chromium in the slag from fluxed heats was in the spinel. The total Cr_2O_3 content (including metal shot) of the fluxed slags was 17·39% as compared to 27·87% for non-fluxed slags; this difference was due mainly to the presence of chromium in the silicate phase (glass + pyroxene) of the non-fluxed slags. However, the total loss of chromium in fluxless smelting was less because of the smaller amount of slag produced.

The Production of Ferro-Alloys in Germany. G. Volkert. (Angewandte Chemie, Series B, 1948, vol. 20, Dec., pp. 341–342). The present economic aspects of the production of ferro-alloys in Germany are reviewed. The electricity requirements for producing 1000 kg. of each of the alloys are shown. In western Germany there are now only two works producing this material. The position is similar to that ruling in 1932. R. A. R.

FOUNDRY PRACTICE

Rate of Heating and Melting Metal in Relation to Cupola Operating Conditions. M. Czyzewski. (Hutnik, 1948, vol. 15, No. 1, pp. 1–15). [In Polish]. The factors affecting the rates of heating and melting metal in the cupola are given detailed consideration. The author's own experiments are described, and graphs and calculations relating these rates to operating conditions are explained.—W. J. W.

Cupola Explosions Due to Scrap. W. H. Spencer. (Pig Iron Rough Notes, 1948, No. 106, pp. 24–25: Chemical Abstracts, 1948, vol. 42, Nov. 10, cols. 8128–8129). Recently in Alabama there was an explosion in a cupola which blew out the side of the furnace. The rivets were broken and the plates bent outward, leaving a hole about 30 in. wide and 10 ft. high in the shell. The causes of such explosions are usually water or oil enclosed or sealed inside the scrap. Of course, when the liquid is heated in the cupola it expands tremendously. Water on merely passing into steam will expand to approximately 1700 times its original volume. Superheating tends to increase this volume even more. It is safest to remember that any solid, liquid or gas which expands more than iron when heated or is of an explosive nature will tend to rupture the iron containing it in the cupola. The severity of the explosion will be governed by the nature of the material causing it and the tightness with which it is sealed into the casting. The rupture may be imperceptible or it may blow the cupola all over the foundry.

The Constant-Charge System of Cupola Operation. W. W. Braidwood. (Institute of British Foundrymen: Mond Nickel Co., Ltd., 1949, Pamphlet). *See* Journ. I. and S.I., 1948, vol. 159, Aug., p. 437.

Mechanical Plugging Device for Melting Furnaces. J. Guillamon. (Fonderie, 1948, June, pp. 1202–1203). An illustrated description is given of a mechanical plugging device for the tapholes of furnaces and cupolas, with particulars of its method of operation and the advantages claimed for it.—J. C. R.

Modernizing a Malleable Foundry. G. L. White. (Canadian Metals and Metallurgical Industries, 1948, vol. 11, Sept., pp. 14–16). A description is given of the steps taken to modernize the foundry of the Galt Malleable Iron Co., Ltd., which produces large numbers of small malleable iron castings. A mechanical moulding line was installed and a new core room and sand-preparation bay were set up, particular attention being paid to ventilation and lighting.—R. A. R.

Cast Iron and Malleable Iron. (Österreichischer Maschinenmarkt und Elektrowirtschaft, 1948, vol. 3, Nov. 30, pp. 373–378). The factors affecting the production of grey and white fractures in cast iron are discussed. The manufacture of grey and malleable cast irons is briefly described. Their properties are given in two comprehensive tables.—R. A. R.

Malleable Annealing Furnaces. G. Joly. (Fonderie, 1948, June, pp. 1187–1197). This is the full text of a paper which appeared in abridged form in *Fonderie*, 1947, Dec., pp. 965–970. (*See* Journ. I. and S.I., 1949, vol. 161, Jan., p. 65).

The Mazières Type of Radiation Arc Furnace. (Informations C.E.M., 1948, No. 1, pp. 3–8: [Abstract] Centre de Documentation Sidérurgique, Bulletin Analytique, 1948, Aug.–Sept., p. 5). The Mazières furnace, made by the Cie. Electro-Mécanique, is of the radiation rocking arc type with single-phase indirect heating, enabling small and medium amounts of metal to be produced economically. Its advantages over the cupola, acid converter, radiation resistance furnace, induction furnace, and Héroult arc furnace are outlined. It can be used for the production of special cast irons, cast steels, and certain special steels.

The Radiation Arc Furnace for Foundry Work. (Journal du Four Electrique, 1948, vol. 57, May–June, pp. 55–58). The principles, operation, and results obtained with the rocking arc furnace are described. This type of furnace, which has the arc above the bath and rocks on rollers to

bring different parts of the bath under the arc, can be used in foundries when the capacity required is up to one metric ton. R. F. F.

Mould Correctly ! The Behaviour of Air in Moulds and Cores. W. Köhler. (Archiv für Metallkunde, 1948, vol. 2, No. 7, pp. 230–237). Many examples of the correct design and positioning of gates and risers and the use of blind risers are cited ; they are taken from a booklet issued by a Düsseldorf firm making core binders.—R. A. R.

Research and Development in the Manufacture of Steel Castings. T. Bishop and K. G. Lewis. (Iron and Coal Trades Review, 1948, vol. 157, Dec. 17, pp. 1349–1357 ; Dec. 24, pp. 1403–1412). In the first part research work in Britain on desulphurization of pig iron, the use of oxygen-enriched air in converters, and problems of fluidity, segregation, burning-on, and hot-tearing are reviewed. The second part deals with the work being done by the British Steel Founders' Association, and the Steel Castings Division of the British Iron and Steel Research Association.—J. C. R.

Pattern and Core Equipment. (B.S.F.A. Bulletin, 1949, vol. 1, Jan.). The preparation of patterns, moulds, and cores is reviewed with illustrated descriptions of the well-known methods.—R. A. R.

Gases Given Off by Core Binders. H. Brown. (Foundry, 1948, vol. 76, Nov., pp. 84–87, 244–245). The author discusses the gases given off by various binders during baking and describes easily duplicated and practical tests to determine the most suitable binder for a given foundry and type of work. Results are given of tests with binders in the following groups : Linseed base, petroleum base, urea resins, and cereal flours. J. C. R.

A Survey of Corebinders and Core-Making Practices. W. M. Dummett. (Institute of Australian Foundrymen : Australasian Engineer, 1948, Oct. 7, pp. 46–49). The core binders and core-making practices employed by foundries in the Sydney district are described.—R. A. R.

New Methods of Making Cores in Swiss Foundries. (Österreichischer Maschinenmarkt und Elektrowirtschaft, 1948, vol. 3, Nov. 30, pp. 378–379). It is stated that a Swiss firm has developed a new core binder having advantageous properties. The setting time for a core made with sand and the new binder can be adjusted over a wide range by adding an accelerator. Large cores can be made with it ; ramming time and knock-out time are very much reduced, and good castings result because of the strength of the core.—R. A. R.

Casting Steel and Iron Rolls. (Foundry, 1948, vol. 76, Nov., pp. 96–99, 199–200). An illustrated account is given of the practice at the Pittsburgh works of Mackintosh-Hemphill Co., where steel and iron rolls are cast.—J. C. R.

Moulding in Cement. G. Kniaginin. (Hutnik, 1948, vol. 15, No. 1, pp. 16–21). [In Polish]. Several examples of cement-sand moulds are described and discussed.

Zinc-Melting Pots. G. Joly. (Fonderie, 1948, July, p. 1244). A brief note is given on factors to be considered in the production of cast-iron pots for melting zinc.—J. C. R.

Investment Castings. W. O. Sweeney and H. L. Mattes. (Machine Design, 1948, vol. 20, May, pp. 91–97). An illustrated description is given of the investment or lost-wax casting process as applied for making small parts of Stellite, Hastelloy, and stainless steel.—R. A. R.

Investment Castings. G. A. Stolze. (Machine Design, 1948, vol. 20, Aug., pp. 139–142). Recommendations are made on methods of preventing defects in small castings made by the lost-wax process.—R. A. R.

Precision Investment Castings Reduce Assembly Operations. E. L. Cady. (Materials and Methods, 1948, vol. 28, Oct., pp. 78–80). Seven examples of small, rather intricate metal parts are illustrated and methods of manufacture are briefly described to show how precision investment casting has considerably reduced the cost. The examples include a three-letter nameplate, arms for pliers of special shape, and a complicated cam for a knitting machine.—R. A. R.

Cause and Cure of Inverse Chill and Hard Spots in Cast Iron. C. A. Zapffe and R. L. Phebus. (American Society for Metals, Oct. 1948, Preprint No. 39). The authors have investigated the causes of inverse chill in grey cast iron and hard spots (zones of retarded graphitization) in malleable iron, and conclude that moisture is the indirect cause and hydrogen segregation the direct cause of both phenomena. It is suggested that the hydrogen content can be reduced sufficiently by taking precautions during melting, tapping, and casting to ensure that hydrogen carriers, particularly moisture, are reduced to a minimum. In cupola melting, the iron can be flushed with a hydrogen-free gas just before casting.—J. C. R.

Aptitude Tests for Foundry Moulders. D. I. Brown. (Iron Age, 1948, vol. 162, Dec. 30, pp. 44–46). Tests applied to experienced moulders have been found to agree well with their supervisors' estimates of their capacity, and have been used in selecting inexperienced workers for a new foundry. The kinds of test which were finally standardized were : Patterns (in which dots have to be linked up to copy a geometrical pattern), personal problems, mechanical information, figure assembly, and spatial relations ; these are not described in detail.—J. P. S.

HEATING FURNACES AND SOAKING PITS

Some Experiences with Soaking Pits. H. V. Flagg. (Iron and Steel Engineer, 1948, vol. 25, Oct., pp. 59–64). Various problems connected with soaking pits, including their heating and automatic control, are discussed.—J. C. R.

Combination Gas-Oil Burners Installed in Continuous Forging Furnaces. (Industrial Heating, 1948, vol. 15, Oct., pp. 1696, 1818). A description is given of the reheating furnaces for forgings for agricultural machinery at the works of the Empire Plow Co., Cleveland, Ohio. The furnaces are 24 ft. long with a capacity of 3300 lb. of steel per hour. They have recently been fitted with 12 burners for either oil or gas and the fuel can be changed from one to the other at a moment's notice.—R. A. R.

New Slab Heating Furnaces at Irvin Works. (Iron Age, 1948, vol. 112, Nov. 4, pp. 118–120 : Steel, 1948, vol. 123, Nov. 22, pp. 84, 86 : Iron and Steel Engineer, 1948, vol. 25, Dec., pp. 102–105). A new slab-heating furnace has been installed by the Carnegie Illinois Steel Corporation. It is fired by coke-oven gas and uses a silicon carbide recuperator. Slabs 3 to 8 in. thick, 20 to 60 in. wide, and 60 to 216 in. long can be treated.—J. P. S.

An Approximate Solution to the Thermal Conductivity Equation and Its Application to Heating Practice. J. Bingel. (Archiv für Metallkunde, 1948, vol. 2, Mar., pp. 106–107). E. Schmidt has developed a graphic method of calculating rates of heat transfer which Timoschenko uses to calculate the stresses in tubes through which hot gases pass. In this paper the author develops an equation for simplifying the calculation by substituting a single expression for the Fourier series used by Timoschenko.—R. A. R.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

The Planning and Economics of Heat-Treatment. H. Schneider. (Stahl und Eisen, 1948, vol. 68, Dec. 2, pp. 479–481). It is deplored that time-studies are not made for heat-treatment processes as often as they should be, and examples are given of methods by which heat-treatment operations can be planned. Specimens of process-data-sheets are shown, the use of which enables fairly accurate estimates of costs to be made.—R. A. R.

Thermodynamics in the Decarburization of Steel with Mill Scale. W. A. Pennington. (American Society for Metals, Oct. 1948, Preprint No. 38). Experiments have been conducted to show that the decarburization of alloy steel strip with mill-scale is effected through two chemical reactions involving gases. A technique of following the effect of different variables on decarburization with mill-scale is established, based on volume measurements of the gases collected. Among the factors investigated were (*a*) total pressure of carbon monoxide and carbon dioxide ; (*b*) effect of inert gases ; (*c*) type of scale used ; (*d*) composition of the steel ; (*e*) temperature ; (*f*) thickness of the steel ; and (*g*) catalysts.

Considerations in the Design of Alloy Support Mechanisms for Pit Type Furnaces. G. C. McCormick. (Industrial Heating, 1948, vol. 15, Oct., pp. 1709–1716, 1837, 1838). A detailed description is given of an alloy steel platform and the brackets supporting it, which formed the load-carrying grid of a vertical cylindrical heat-treatment furnace 4 ft. in dia. by 8 ft. deep. This grid, together with the castings, was quenched in the oil bath and failures occurred after about 90 quenches. A detailed description is given of the new design adopted to overcome these difficulties. Three box or tubular beams with generous radii were employed in place of six **I** beams, and new hanger links were designed.—R. A. R.

Heat Treating Used to Vary Properties of Precision Cast Materials. E. L. Cady. (Materials and Methods, 1948, vol. 28, Dec., pp. 72–75). Examples are given of the manner in which the strength of precision investment castings in molybdenum steels, stainless steel, and some non-ferrous alloys is improved by heat-treatment. Several heat-treatment procedures are described.—R. A. R.

Metallurgy and Heat Treatment of Cutting Tools. P. Leckie-Ewing. (Iron Age, 1948, vol. 162, Dec. 30, pp. 28–33; 1949, vol. 163, Jan. 13, pp. 60–64). The importance of small inherent grain-size and fine, evenly distributed, carbide particles in such high-speed alloy steels as the 18/4/1 tungsten–chromium–vanadium and 6/5/4 chromium–tungsten–molybdenum alloys is stressed. Methods of heat-treatment to avoid surface carburization or decarburization are discussed, and the values of nitriding and chromium-plating are considered.—J. P. S.

Tool Steel. F. van Wijk. (Metalen, 1948, vol. 3, Dec., pp. 84–87). [In Dutch]. Methods of heat-treating tool steel are reviewed and a method of classifying them according to their hardenability and mechanical properties, as advocated by the Carpenter Steel Company, is explained.—R. A. R.

Heat Treating Parts for Apex Appliances. (Industrial Heating, 1948, vol. 15, Nov., pp. 1908–1916). A description is given of the heat-treating plant of the Apex Electrical Manufacturing Co., Cleveland, Ohio, for heat-treating small parts of washing and ironing machines. It includes a cyanide bath heated by immersed electrodes, a gas-carburized furnace also electrically heated, a tempering furnace, as well as cleaning and quenching equipment.—R. A. R.

The Heat-Treatment of Some Nickel–Chrome–Molybdenum Steels. J. H. Moore. (Australian Institute of Metals: Australasian Engineer, 1948, Oct. 7, pp. 55–61). Details are given of the heat-treatment practices for three types of low-alloy steel at the Government Ordnance Factory, Maribyrnong, Victoria. The three types are 4·3/1·2/0·2, 2·6/0·75/0·5, and 1·5/0·8/0·5 nickel–chromium–molybdenum steels. R. A. R.

Heat Treatment and Surface Finishing of Stainless Steel. W. F. Walker. (Mechanical World, 1948, vol. 124, Nov. 26, pp. 606–609). Recommendations are made on the stress-relieving heat-treatment for stainless steels and methods of surface treatment including degreasing, cleaning, descaling, electrolytic pickling and chemical descaling, grinding, polishing, surface etching, and passivating (*i.e.*, speeding-up the formation of the protective oxide coating).—R. A. R.

Solid Carburizing—Metallurgy and Production. E. W. Cox. (Australian Institute of Metals: Australasian Engineer, 1948, Oct. 7, pp. 65–75). The theory of pack-carburizing is explained and the process is described in detail with special reference to the structures obtained by different heat-treatments after the carburization.—R. A. R.

High-Temperature Electrode Salt Baths. G. B. Lamb. (Overseas Engineer, 1948, vol. 22, Jan., pp. 208–210). A detailed description is given of a salt-bath furnace, heated by immersed electrodes, and the operating procedure for heat-treating hot-die steels and high-speed steels using the salt Carboneutral.—R. A. R.

Atmospheres for Clean Hardening and Carburizing. F. E. Harris. (Metal Progress, 1948, vol. 54, Sept., pp. 337–343). The theory of the action of carburizing gases on steel is explained and it is shown how to compute the effect of pressures, both gaseous and solid, on gas compositions for equilibrium with carbon at 1500° F. when the atmosphere is diluted with nitrogen, or when the steel has any given carbon content. Carburizing and decarburizing experiments are cited. It is shown that a metal containing 0·2% of carbon can be carburized to obtain a carbon gradient from 0·90% at the surface to 0·50% as no gradient is possible at 1400° F. between 0·50% carbon and the saturated ferrite (*i.e.*, the core with only 0·02% of carbon); there is therefore a sharply demarcated surface dividing the phases austenite with 0·50% of carbon and ferrite at the temperature of the process (1400° F.), and this interface moves inwards with time.—R. A. R.

Gas Carburising. D. M. Dovey and I. Jenkins. (G.E.C. Journal, 1948, vol. 15, July, pp. 63–80). The reactions occurring within a carburizing box are discussed. A comparison is made of various carburizing atmospheres tested in the laboratory and this leads to a consideration of the effects of differences in concentration of certain constituents of the atmospheres. The mechanism of 'sooting,' the importance of gas recirculation, methods of gas generation, and the design of furnaces and gas generators are discussed. The flexibility of control obtainable during carburization is illustrated by reference to a commercial plant.—R. A. R.

Examples of Modified Isothermal Treatments with a View to Obtaining a Minimum Deformation. O. E. Brown. (Revue du Nickel, 1948, vol. 14, Jan.–Mar., pp. 16–18).

Laboratory Lamp Generator for Hardening and Melting Metals. Yu. M. Bogatyrev and M. B. Berezhinskii. (Zavodskaya Laboratoriya, 1947, vol. 13, pp. 890–891: Chemical Abstracts, 1948, vol. 42, Nov. 20, cols. 8739–8740). An electrical diagram is given of a lamp generator for hardening and melting metals on a laboratory scale. The essential difference from ordinary powerful lamp generators is the absence of a rectifier; the lamps are fed directly from a line of 220–280 V. which is transformed into 1000 V. One kg. of steel can be melted in 15–17 min.; the maximum amount of molten steel cannot exceed 2 kg.

Radio-Frequency Heating. L. Hartshorn. (Proceedings of the Royal Institution of Great Britain, 1945–46, vol. 33, Part IV, pp. 541–553). The theory of radio-frequency heating is discussed with explanations of the transfer of power to the work and its absorption by the work. Examples are described of the heating and hardening of gear-wheel teeth, and of the curing of plastic material by dielectric heating.—R. A. R.

Cover Type Annealing Furnaces Speed Production for the Columbia Steel Co. (Industrial Heating, 1948, vol. 15, Nov., pp. 1882–1890). A description is given of the new plant at the works of the Columbia Steel Co., Pittsburg, Cal., for annealing cold-reduced coils of strip. It consists of 30 bases each capable of carrying eight stacks of coils piled 12 ft. 6 in. high, and ten rectangular furnaces fired with radiant tube gas combustion units; the furnaces can be lifted and lowered on to any of the bases.—R. A. R.

Practical Aspects of Isothermal Annealing. J. Shaw. (Steel Processing, 1948, vol. 34, Nov., pp. 600–604, 613). The theory of isothermal heat-treatment is explained by reference to TTT curves (transformation–time–temperature), and the principles to follow in selecting a suitable treatment, as given by Payson, are discussed. The higher the austenitizing temperature employed, the greater is the tendency for a lamellar structure to be formed during transformation; the lower the temperature, the greater the tendency for a spheroidal structure to be formed after transformation. When the rate of transformation varies considerably with change in transformation temperature it is common practice to employ two transformation temperatures, one 10° C. above, and the other 10° C. below, the optimum temperature as determined in the laboratory. This treatment is very useful in annealing the steels of the high manganese non-distorting type, particularly when small amounts of chromium, tungsten, and vanadium are present. A procedure for annealing two high-speed steels (W 18%, Cr 4%, V 1% and W 18%, Cr 4%, V 1%, Co 10%) in the same furnace so as to economize fuel is outlined.—R. A. R.

Isothermal Heat-Treatment for Precision Hardening. C. T. Wilshaw. (Metallurgia, 1948, vol. 39, Nov., pp. 3–6). The theory of the martempering or isothermal quenching process is explained by comparing the cooling curves for the surface and centre of martempered bars with those of oil-quenched bars. In the former case the temperature across the section reaches uniformity before hardening commences and there is therefore practically no distortion during subsequent hardening and cooling. A martempering plant is described with details of the procedure for hardening and tempering a manganese steel (C 1%, Mn 1·5%) fuel-pump barrel 5 cm. long with outside and inside diameters of 18·5 and 7·5 mm. respectively.

FORGING, STAMPING, DRAWING, AND PRESSING

A Modern Heavy Forging Plant. W. H. Alvey. (Journal of The Iron and Steel Institute, 1949, vol. 161, Feb., pp. 119–138). Descriptions are given of six heavy forging presses at the works of the English Steel Corporation, Ltd., the auxiliary machinery, the work performed, reheating furnaces, cranes, and general maintenance. The presses comprise two 1430-ton single-cylinder type, two 2250-ton twin-cylinder type, one 4000-ton twin-cylinder type, and one 7000-ton single-cylinder type. Five of them were installed between

1900 and 1913 and the sixth (2250 tons) was installed in 1943. All of them are now equipped with electrically driven, high-pressure, three-throw, horizontal pumps, operating at a maximum working pressure of 2½–3 tons/sq. in.—R. A. R.

Forging. R. Barat. (Machines et Métaux, 1948, vol. 32, July, pp. 213–217; Dec., pp. 421–425). In the first part of the article the author discusses the flow of metals during forging, drawing, rolling, and stamping. In the second part the author deals with the effect of speed of forging on the metals, such as resistance to deformation, tendency to cracking, rise in temperature and deformation.—R. F. F.

Suitability of Metals for Forging. P. Bastien. (Machines et Métaux, 1948, vol. 32, Dec., pp. 403–410). The mechanical and physical properties of metals which affect the forgeability are discussed. Forgeability tests and the effect of structural changes after casting are also mentioned.—R. F. F.

The Forging of Rolls with Special Reference to Forging Equipment Required for It. B. Wiele. (Archiv für Metallkunde, 1948, vol. 2, No. 6, pp. 205–207). The sequence of operations in a heavy forging shop for making rolling-mill rolls of 0·59–0·74% carbon steel and of a chromium steel (C 0·80–0·90%, Cr 1·6–1·9%) is described with notes on the heat-treatment applicable to each.—R. A. R.

Drop Forging. G. Wilson. (E.S.C. News, 1948, vol. 2, No. 3, pp. 3–8). Drop and board hammers and forging presses are described and illustrated with examples of the parts which can be made with them.—R. A. R.

Production of Forgings for Carnegie Tech. Cyclotron. O. H. Baker. (Industrial Heating, 1948, vol. 15, Oct., pp. 1654–1662, 1844). Particulars are given of the manufacture and dimensions of the magnet and other parts of the cyclotron to be erected at the Carnegie Institute of Technology. The finished magnet will weigh 1465 tons and it will have 12 ft. pole pieces. To make it 24 ingots ranging in weight from 20 to 225 tons have been cast; these were reheated and brought up to the forging temperature of 2300° F. and forged in a 7000-ton hydraulic press having two 50-in. dia. plungers with an operating stroke of 8 ft. at 3-in./min. and making a maximum of 50 strokes/min. The press has three centrifugal water pumps in series each driven by a 1000 h.p. motor. Many of the operations are illustrated.—R. A. R.

Suggestions Given for Fabrication of Pressure Vessels from Stainless Alloys. (Petroleum Processing, 1947, vol. 2, Apr., pp. 314–315). This article discusses the application of nine stainless steels in the manufacture of pressure vessels.

Forming Operations on Stainless Steel. W. F. Walker. (Mechanical World, 1948, vol. 124, Nov. 5, pp. 519–524). Descriptions are given of the tools and techniques for the following operations on stainless steel: Shearing, blanking and piercing, forming, deep-drawing, rolling, bending (including bending tubes), embossing, spinning, forging, upsetting, and flame-cutting.—R. A. R.

The Design of Small Parts and Their Shaping without Removing Metal. K.-H. Sieker. (Archiv für Metallkunde, 1948, vol. 2, Mar., pp. 87–93). The folding, pressing, deep-drawing, and die casting methods of shaping metals into small parts are reviewed and their advantages, limitations, and applications are discussed.—R. A. R.

Hot Pressed Formed Parts for Heavy Construction. H. A. Ottey. (Product Engineering, 1948, vol. 19, Nov., pp. 113–116). Examples of formed steel parts up to 3½ in. thick produced by hot pressing are described and illustrated, and the advantages of pressing as compared with casting are pointed out and data on dimensional tolerances are given. R. A. R.

The "Simultan" Deep-Drawing Process. G. Oehler. (Archiv für Metallkunde, 1948, vol. 2, No. 6, pp. 199–205). The effect of pauses between the stages of drawing in deep-drawing operations is pointed out and the "Simultan" deep drawing process is described. In this the ram is surrounded by two concentric sleeves and the dies consist of corresponding concentric sleeves. Each ram and die has its own independently controlled hydraulic cylinder which enables the three stages of drawing to be accomplished in sequence without interruption. The "Auble" process, which also employs a telescopic ram but has fixed dies, is also described and diagrams are presented showing the differences in power requirements as drawing proceeds in the three processes, *i.e.*, ordinary deep-drawing in three separate operations, Auble drawing, and Simultan drawing.—R. A. R.

The Application of Phosphate Coatings to Wire, Tube and Deep Drawing. H. A. Holden and S. J. Scouse. (Sheet and Strip Metal Users' Technical Association: Sheet Metal Industries, 1949, vol. 26, Jan., pp. 123–134, 136). The progress made, particularly in Germany, in the application of phosphate coatings to steel to facilitate drawing is reviewed. The process of Bonderizing and the properties of the coating are discussed, and wire drawing, tube drawing, deep drawing and cold extrusion operations are described with special reference to the advantages gained by the phosphatizing treatment. The crystalline phosphate layer does not act merely as a carrier for the lubricant, but also takes part in the deformation without itself becoming detached from the parent metal. The use of Bonderized wire for cold-heading bolts is being developed. It results in a marked increase in die life.—R. A. R.

The Calculation of Drawing Strains in Circular Shells. K. L. Jackson. (Journal of the Institution of Production Engineers, 1948, vol. 27, Dec., pp. 709–724). The author attempts to show how the plastic strains arising when a cylindrical body is drawn from a flat circular blank may be evaluated under the conditions of certain assumptions, and to analyse the mechanics of drawing. The photogrid technique was employed to examine the distribution of radial strain, and measurements were made of the radial, hoop, and thickening strains. Graphs were constructed to show the nature of the strain distribution in the case of 0·010 in. tinplate.—R. A. R.

Theory of Plastic Deformation. E. Siebel. (Archiv für Metallkunde, 1948, vol. 2, No. 7, pp. 248–252). Formulæ and methods for calculating the stresses involved and work done in several processes of plastic deformation are discussed with 37 references to the literature. The processes include (*a*) drawing and rolling strip without increase in width, (*b*) drawing wire and rods, (*c*) drawing tubes, (*d*) deep-drawing, and (*e*) punching.—R. A. R.

The Calculation of Stresses in the Ironing of Metal Cups. R. Hill. (Journal of The Iron and Steel Institute, 1949, vol. 161, Jan., pp. 41–44). The paper describes a theory of the stresses required to iron a cup by forcing it through a die with a close-fitting internal punch. It is assumed that the wall of the cup is thin enough for the deformation to be effectively plane strain. An accurate theory, based on a calculation of the slip-line field and the shape of the plastic region, is then available. The ironing load is evaluated for the practical range of reductions and die angles. Friction and work-hardening are taken into account.

Some Fundamental Considerations of the Deep Drawing of Metals. A. R. E. Singer. (Sheet and Strip Metal Users' Technical Association: Steel Processing, 1948, vol. 34, Oct., pp. 530–533; Nov., pp. 595–597). *See* Journ. I. and S.I., 1948, vol. 160, Oct., p. 225.

Modern Cold Drawn Equipment. G. W. Garwig and A. L. Thurman. (Iron and Steel Engineer, 1948, vol. 25, Oct., pp. 90–100). Details are given of some developments in draw benches and auxiliary equipment for the production of cold drawn bars and tubes. Illustrated descriptions are included of push pointers and hydraulic squeeze pointers for reducing the end diameter of tubes and bars, and the advantages of these types of equipment are outlined.—J. C. R.

Selecting Steel for Deep-Drawing Sheets. F. Eisenkolb. (Archiv für Metallkunde, 1948, vol. 2, No. 7, pp. 217–223). Factors which affect the drawing properties of steel sheet are reviewed. Carbon, nitrogen, sulphur, and phosphorus must all be kept very low. Basic-Bessemer steel is unsuitable unless made by the process which reduces the nitrogen and phosphorus to very low amounts. Examples of segregation in ingots are cited, and a scheme for the utilization for different purposes of different horizontal sections of 5-ton ingots of unkilled steel is shown in which the first and last sixths (from top to bottom) are used for making ordinary sheets, the second and third sixths for deep-drawing, and the fourth and fifth sixths for ordinary drawing.—R. A. R.

History and Development of Wiredrawing Machinery. R. S. Brown. (Transactions of the Manchester Association of Engineers, 1947–48, pp. 245–259). After a brief review of the history of wire-drawing from the earliest hand-drawing methods, the author describes the tungsten carbide die and discusses lubrication, changes in properties of the wire caused by drawing, and experience in the performance of

wires in suspension bridge cables and for railway signalling. Cyclic curves show that wires subjected to repeated loading gradually lose their plastic properties, whereas the same wires bent round pulleys under the same conditions of loading retain their plastic and hysteresis properties unimpaired. R. A. R.

An Investigation into the Inhomogeneity of Deformation in Wire Drawing and Rolling. J. Collins and R. W. K. Honeycombe. (Journal of the Council for Scientific and Industrial Research, Australia, 1948, vol. 21, Feb., pp. 59–65). A method involving the detection with the microscope of the beginning of recrystallization in deformed metals is employed for investigating the inhomogeneity of familiar deformation processes. Some results obtained by it when drawing brass wire and rolling brass sheet are presented and discussed. R. A. R.

A Feeler Gauge for Wire-Drawing Dies. H. Mucke. (Stahl und Eisen, 1948, vol. 68, Dec. 2, p. 484). The difficulties encountered in designing gauges to determine the contours of wire-drawing dies are discussed and two instruments are proposed. One is intended for taking readings of the feeler movement and constructing a curve, whilst the other automatically inscribes the curve.—R. A. R.

ROLLING-MILL PRACTICE

The Development in the Demand, and Planning the Production of Rolled Steel. W. Asbeck. (Revue de Métallurgie, Extraits, 1948, vol. 45, Oct., pp. 261–265). This is a French translation of an article which appeared in Stahl und Eisen, 1947, vol. 66–67, Nov. 6, pp. 389–395. (*See* Journ. I. and S.I., 1948, vol. 158, Mar., p. 400).—R. F. F.

Rolled Bars. Part I. Calculation of Spread between Non-Parallel Roll Surfaces. Part II. Application of Spread Calculation to Pass Design. A. E. Lendl. (Iron and Steel, 1948, vol. 21, Sept., pp. 397–402; Dec., pp. 601-604). Formulæ for calculating spread are based upon a reduction between parallel surfaces of the rolls, but, in practice, this seldom takes place and rolling is usually effected between parts of the roll which are not parallel, *i.e.*, in grooves cut in the roll cylinders. The author investigates the rolling of a bar between non-parallel surfaces and the extent to which the known formulae for the calculation of spread can be used for ascertaining the spread in grooves. In the second part a method of calculation is presented to enable the roll pass designer to lay out the individual grooves correctly, also the sequence of alternate square and oval passes, in such a way that no additional adjustment is required during production.—J. C. R.

Roll Bearings and Their Lubrication. B. Marzecki. (Hutnik, 1947, vol. 14, No. 12, pp. 563–579). [In Polish]. Different types of rolling-mill bearings are described and critically examined from the practical point of view. Special attention is given to fluid-film bearings because of their long life and low coefficient of friction.—W. J. W.

Lubricants for Cold Rolling Steel. R. J. Nekervis and R. M. Evans. (Iron and Steel Engineer, 1948, vol. 25, Oct., pp. 72–81) This is a report of an investigation to find a substitute for palm oil in the cold reduction of steel strip. Lubricant requirements are considered and the method of evaluating lubricating properties is described. This was the measurement of the coefficient of friction on a laboratory cold rolling mill with all rolling variables, except reduction in thickness and pressure, either held constant or varied at equal rates and by equal amounts. The method of testing rolling performance and the evaluation of cleaning properties and lustre for the substitute lubricants are outlined.—J. C. R.

Columbia Steel's New Sheet and Tin Mill. P. F. Kohlhaas. (Iron and Steel Engineer, 1948, vol. 25, Oct., pp. 42–58). A detailed and illustrated description is presented of the new cold reduction mill and finishing plant of the Columbia Steel Company at Pittsburg, California. Plans are given of the general layout of the plant, the 5-stand cold reduction mill, the electrolytic cleaning line, the auxiliary sheet shearing line, the electrolytic tinning line, and the 42-in. continuous tinplate shearing line. The processes involved in the production of cold-reduced sheets, the production of electrolytic tinplate, and in hot-dip tinning operations are fully outlined. J. C. R.

Cold Rolling Technique. Part I—Explanation of Terms and Theories Used. Part II—The Effect of Speed on Cold Rolling Practice. H. Ford. (Sheet Metal Industries, 1948, vol. 25, July, pp. 1327–1336, 1344; Aug., pp. 1545–1549; Sept., pp. 1757–1762; Oct., pp. 1973–1978; Nov., pp. 2189–2197; Dec., pp. 2405–2411, 2418). This series of articles is intended to be a practical introduction to the study of cold rolling. The terms and theories used having been explained in Part I, the effect of speed is dealt with in Part II. To reduce the speed effect the work-roll diameter should be as small as possible, consistent with the work to be performed. Change of gauge with speed is not solely dependent upon the change in roll contour resulting from the smaller roll force. The drop in the roll-separating force causes a corresponding drop in the elastic deflections of the mill frame, screws, etc., and the total effect may be considerable, especially in heavily loaded mills. The speed effect is most serious at very low speeds and is less serious for smaller than for heavier pass reductions for the same final strip thicknesss. High strip tensions reduce roll force; the lower the roll force the less is the amount of roll-flattening; high strip tension should therefore render less serious the effects of speed changes.—R. A. R.

The Y Cold Strip Mill. A. I. Nussbaum. (British Steelmaker, 1948, vol. 14, Dec., pp. 571–573). In a paper by Lueg and Pomp it was shown that the most efficient mill for cold rolling strip is the one able to take heaviest reductions using the smallest diameter work rolls. This has been the guiding principle in the design of the **Y** mill. A typical mill of this type is described. Its rolls are 20 in. long. The upper and lower work rolls are $3\frac{1}{4}$ in. and $6\frac{1}{4}$ in. in dia. respectively, and the lower backing roll is $19\frac{1}{2}$ in. in dia. The upper work roll is supported by two $6\frac{1}{4}$ in. dia. intermediate rolls, each of which is supported by a $17\frac{3}{4}$ in. dia. backing roll. The axes of each pair of upper backing rolls are at 45° to the horizontal. The 600 h.p. mill motor is directly connected to the three $6\frac{1}{4}$ in. dia. rolls. Roll adjustment is made by screwing the lower rolls up or down.—R. A. R.

Electric Motor Rollers. K.-H. Idar. (A.S.E.A's Tidning, 1948, vol. 40, No. 8–10, pp. 89–102). The author gives some general features of rolling-mill trains and then describes motor-driven mill tables giving detailed information on their design and the calculations for the motors. In conclusion he gives detailed information on the speed regulation of motor-driven tables.—J. K.

WELDING AND FLAME-CUTTING

The Calculation of Welded Joints in Machinery Construction. A. Thum and A. Erker. (Österreichischer Maschinenmarkt und Eisenhandel, 1948, vol. 3, June, pp. 171–176; July, pp. 204–205; Aug., pp. 226–227). The design calculations for welds in machinery construction are explained with examples, the information being taken from the authors' book. "*Schweissen im Maschinenbau.*"—R. A. R.

The Role of Oxygen in Electric Welding. J. D. Fast. (Mededeelingen van de Vlaamsche Chemische Vereeniging, 1948, vol. 10, pp. 1–21: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8769). The use of SiO_2-coated welding rods for electric welding of iron and steel reduces the oxygen dissolved in iron from 0·18–1·19% with the use of uncoated rods, to 0·12% with a SiO_2 coating with an addition of FeMn and Fe_2Si, and to 0·03% when the slag formed contains only oxides the heat of formation of which ($\Delta H/g.$ atom O) is very high, such as Al_2O_3, BeO, BaO, CaO, MgO, SiO_2 (quartz), TiO_2, ZrO_2. Another type of rod contains in its coating large amounts of organic substances, which develop large quantities of gas during the welding, thus keeping the oxygen and nitrogen away from the metal. The formation of hydrogen and carbon monoxide porosity in welds is discussed.

Some Metallurgical Experiences Associated with the Testing of Welding Electrodes. E. J. R. Copp. (Australian Welding Institute: Australasian Engineer, 1948, Sept. 7, pp. 65–71). The author criticizes the use of heat-treatment terms to describe the properties and behaviour of welded joints, by showing, among other things, that the deposition of multi-run welds produces neither an 'annealing' nor a 'normalizing' effect. Similarly, although a specimen cut from deposited weld metal may be ductile in a tensile test, the ductility of a joint made with the same electrodes will depend upon the weldability of the parent metal and the welding technique. Tentative suggestions for a method of classifying electrodes are made.—R. A. R.

The Fatigue of Welds. M. Roš. (Société Française de Métallurgie, Oct. 10, 1947 : Revue de Métallurgie, Mémoires, 1948, vol. 45, Nov., pp. 421–446). As a means of evaluating the quality of butt weld the fatigue test is superior to static stressing because defects in the material, the weld metal or the method of welding are shown up more clearly ; runs that have not welded on properly or which contain fine cracks will fail in time under fatigue stressing. The author summarizes the fatigue strengths of a number of types of butt weld in mild steel, explains the theory of the determination of the quality of welds and its calculation, and discusses the stresses permissible in the welds of welded steel structures.—A. E. C.

Effect of Weld Metal Composition on the Strength and Ductility of 15% Cr–35% Ni Welds. D. Rozet, H. C. Campbell, and R. D. Thomas, jun. (Welding Journal, 1948, vol. 27, Oct., pp. 481-s–491-s). The optimum composition for weld metal in welds in 15/35 chromium–nickel steels has been established ; the same composition limits are found to apply in the case of 18/38 steel. Where carbon is 0·15–0·25%, silicon 0·20–0·60%, manganese 1·00–2·00%, and sulphur and phosphorus each 0·025% max., ultimate tensile strengths of 35·7–40·2 tons/sq. in. can be obtained with elongations of 30–40% on 2 in. Within this range of compositions the tensile specimens are free from fissures, especially if the carbon is kept in the neighbourhood of the upper limit : side-bend tests on welds are satisfactory. While niobium increases soundness, it reduces ductility, and is regarded as an undesirable addition ; if silicon is introduced to resist oxidation or carburization, the limit of carbon content should be raised to 0·40%.—J. P. S.

Does the Welding Sequence Affect the Contraction Stresses? M. Hansen. (Dansk Teknisk Tidsskrift, 1948, vol. 72, Dec., pp. 209–215). [In Danish].

The Technique of Resistance Welding. P. van Nooyen. (Lastechniek, 1948, Sept., pp. 113–117 ; Oct., pp. 119–122 ; Nov., pp. 134–137). [In Dutch].

The Application of Resistance Welding to Sheet Metal Practice. L. H. Park. (Sheet Metal Industries, 1948, vol. 25, Dec., pp. 2487–2498). A detailed description is given of the technique of electric resistance spot and seam welding, with notes and recommendations concerning the difficulties encountered : Electric riveting and soldering are also described. R. A. R.

The Use of Welding Manipulators, Turning and Tilting Stands. W. A. J. Nolen. (Lastechniek, 1948, vol. 14, Dec., pp. 147–150). [In Dutch].

Jointing Stainless Steels. W. F. Walker. (Mechanical World, 1948, vol. 124, Nov. 19, pp. 574–577). Recommendations are made on the techniques for riveting, soldering, electric welding, and gas welding stainless steel.—R. A. R.

Submerged Melt Welding Structural Steel Sections. J. M. Tippett. (Steel, 1948, vol. 123, Dec. 27, pp. 58–60, 91). Submerged arc welding is very suitable for the fabrication of **I, H,** and box-section beams from plates.—J. P. S.

Repairing Gray Iron Castings by Welding. L. Ames. (Iron Age, 1948, vol. 162, Dec. 23, pp. 46–51). Instances of the repair of grey iron castings by gas welding with either cast-iron or bronze filler rods are fully described.—J. P. S.

Electric Welding a Vacuum Pump without Preheating. E. Hawlik. (Schweisstechnik, 1948, vol. 2, Nov., pp. 131–134). A description is given of the welding technique employed in the repair of a very large cast-iron crosshead of a pump used in a brewery. The measures adopted to reduce the residual stresses included using small-diameter electrodes for the first runs, depositing short beads at first and making pauses between successive beads until the whole casting was heated up, when the pauses were shortened, and commencing to weld at the point of maximum stress concentration and running the bead towards the point of minimum stress. R. A. R.

Furnace Brazing with Pressed Metal Parts. H. M. Webber. (Steel Processing, 1948, vol. 34, Sept., pp. 469–474 ; Oct., pp. 554–556). Several examples of the furnace brazing of pressed metal parts are described ; they demonstrate the economic advantages of this method of joining.—R. A. R.

Gas-Cutting of Stainless Steel. W. H. Simon. (Canadian Machinery, 1948, vol. 59, Mar., pp. 118–120, 122, 124 ; Apr., pp. 132, 134, 136, 138, 140 : [Abstract] Centre de Documentation Sidérurgique, Bulletin Analytique, 1948, vol. 5, p. 25). The cutting of stainless steel by the oxygen arc method and the oxy-acetylene flame method using a special flux is discussed.

The Cutting of Stainless Steel and Cast Iron. A. Labrie. (Lastechniek, 1949, vol. 15, Jan., pp. 162–165). [In Dutch]. Techniques for oxy-acetylene cutting stainless steel and cast iron, and the equipment are described and illustrated with special reference to the process in which a stream of powder is entrained with the cutting gas.—R. A. R.

MACHINING AND MACHINABILITY

The Metallurgical Aspects of the Machinability of Steel. L. W. Johnson. (Journal of the Institution of Production Engineers, 1948, vol. 27, Dec., pp. 725–755). The literature on the manner in which the machinability of steel is influenced by its metallurgical condition is reviewed with special reference to (*a*) general physical condition (whether cast, wrought, cold worked), (*b*) chemical composition, (*c*) type of microstructure, (*d*) grain size, (*e*) non-metallic inclusions, (*f*) surface condition, and (*g*) mechanical properties. One appendix reports an investigation of the relationship between machinability and microstructure of three low-alloy steels (Ni 1·81%; Cr 1% ; Ni 1·80%, Cr 0·84%, Mo 0·20% ; Cr 0·95%), and a second appendix gives tables of the compositions of many S.A.E., N.E., and En steels.—R. A. R.

Control of Surface Finish Improves Quality, Cuts Cost. H. R. Clawser. (Materials and Methods, 1948, vol. 28, Oct., pp. 74–77). The terms used by the American Standards Association for defining surface roughness, are given and the advantages of controlling it are discussed. The characteristics of machining corrugations are called ' lay ' and ' roughness ' (direction and height of the corrugations), irregularities at a greater spacing than the corrugations are called ' waviness.' They may be measured as maximum peak-to-valley height, average peak-to-valley height, and deviation from the mean surface.—R. A. R.

CLEANING AND PICKLING

Metal Cleaning. T. C. Du Mond. (Materials and Methods, 1948, vol. 28, Nov., pp. 83–94). An illustrated survey of metal-cleaning processes is presented. Processes, including acid, alkali solvent, electrolytic, emulsion, and mechanical cleaning are described first, and this is followed by recommendations on the cleaning of specific metals.—R. A. R.

The Relation of Finishing to Design, Materials and Processing Methods. E. Engel. (Metal Finishing, 1948, vol. 46, Nov., pp. 61–67, 81). Factors affecting the selection of coating and polishing processes for finishing parts are enumerated and discussed, and the limitations of polishing, plating anodizing and lacquering are pointed out, data on the response of non-ferrous and ferrous metals to various plating processes being given.—R. A. R.

Shot Peening—A Survey of Modern Methods and Applications. G. T. Colegate. (Sheet Metal Industries, 1949, vol. 26, Jan., pp. 141–148, 152 ; Feb., pp. 371–380, 384). The paper reviews all aspects of shot-peening by describing the development and mechanism of the process, the shot and machines used, and the method of removing broken shot, and discussing shot size, the peening of sheet, testing peening intensity, and special applications of the process.—R. A. R.

How Surface Peening Improves Metal Parts. R. Mansell. (Steel Processing, 1948, vol. 34, Oct., pp. 549–551, 556). Examples are described of the manner in which shot-peening increases fatigue strength, decreases stress corrosion cracking, imparts additional strength to parts weakened by decarburization of the surface, and improves the lubricating properties by providing minute pockets which store oil.—R. A. R.

Shot-Blasting Replaces Pickling on Some Steel Cleaning Applications. K. Rose. (Materials and Methods, 1948, vol. 28, Nov., pp. 72–75). A description of the Wheelabrator shot-blasting process is given and the conditions under which it can and cannot compete with acid-pickling are discussed. With the Wheelabrator machine the abrasive, chilled iron or steel shot or sand, is carried in a hopper and feeds by gravity to the centre of a bladed wheel 19½ in. in dia. revolving at 2250 r.p.m. The amount of abrasive fed to each blade is controlled by a stationary cage at the centre of the wheel. About 300 lb./min. of shot are flung from the wheel. The equipment can be adapted to either batch or continuous operation.—R. A. R.

Molten Salt-Bath Descaling Process. S. G. Osborne and H. R. Spence. (Steel, 1948, vol. 123, Dec. 13, pp. 106–110, 124, 126, 129, 130, 132). Molten salt descaling using a proprietary compound known as "Virgo" is described. After dipping in this compound, at 480–530° C., the work is quenched in water, and a residual oxide film removed in a dilute acid bath. Apart from replacement of "drag-out" the only attention required is occasional de-sludging of the salt-bath. (*See* "Molten Salt Descaling by the Efco-Virgo Process," Journ I. and S.I., 1949, vol. 161, Feb., p. 157).—J. P. S.

Effective Handling Arrangement Boosts Pickling Production. D. Reebel. (Steel, 1948, vol. 123, Dec. 27, pp. 54–57). At Lamson and Sessions Co., Cleveland Works, the pickling and liming of wire in 1200-lb. coils is handled automatically, preparatory to drawing for the manufacture of bolts and screws for sheet metal.—J. P. S.

Cleaning of Sheets before Enamelling. P. Tyvaert. (Fonderie, 1948, June, pp. 1204–1205). A brief practical note is given on the cleaning of sheets, intended for enamelling, using a hot alkaline solution.—J. C. R.

The Relative Merits of Sulphuric and Hydrochloric Acids for Pickling. J. H. G. Willan. (Sheet Metal Industries, 1948, vol. 25, Dec., pp. 2415–2418). Sulphuric and hydrochloric acids for pickling are compared. When silicates are present and when articles are to be enamelled, tinned or galvanized, hydrochloric acid is preferable. Sulphuric acid pickling allows a little more latitude in the pickling process, and inhibitors are slightly more efficient with this acid. In the problem of disposing of liquor, sulphuric acid has a decided advantage.—R. A. R.

Driving and Controlling a Modern Strip Pickling Line. J. R. Erbe. (Iron Age, 1949, vol. 163, Jan. 13, pp. 46–50). The application of semi-automatic and automatic controls on the conveyors, coilers, welders, and rolls on the continuous pickling line at Jones and Laughlin Steel Corporation's Aliquippa plant is described. Rototrols are used on the motors involved, and ignitron contactors and synchronous timers on the welders.—J. P. S.

Some Notes on the Uses and Effects of Inhibitors in the Acid Pickling of Iron and Steel. P. de Lattre. (Sheet Metal Industries, 1948, vol. 25, Oct., pp. 1961–1964; Nov., pp. 2181–2188). The characteristics and action of three classes of pickling inhibitors, namely, the amino acids, products of marked polar character such as the formaldehydes, and tertiary heterocyclic bases and alkaloids and dyes derived from them, are discussed with numerous references to the literature and patents.—R. A. R.

The Effect of Inhibitors during Pickling. K. Wickert. (Archiv für Metallkunde, 1948, vol. 2, No. 4, pp. 137–139). Weight-loss tests were made using iron electrodes immersed in hydrochloric acid in separate flasks with and without the addition of a proprietary inhibitor. The loss in weight of both anode and cathode was considerably reduced by adding the inhibitor, the reduction for the latter being much greater. The addition of the accelerator NaCl increased the loss by the anode much more than that by the cathode. R. A. R.

Disposing of Waste Pickle Liquors. L. J. Wieschhaus. (Occupational Hazards, 1948, vol. 10, No. 11, pp. 15, 43: Chemical Abstracts, 1948, vol. 42, Nov. 20, cols. 8764–8765). This is a review of the hazards attendant with acid pickling operations while removing scale and oxides from metal, and suggestions for some practical preventive measures.

Absorption Studies with Waste Pickle Liquor. J. Seiberlich. (University of New Hampshire, Engineering Experiment Station, Engineering Publication No. 6; Steel, 1948, vol. 122, Jan. 12, pp. 90, 97–98). The absorption of ferrous sulphate from pickling liquors containing an excess of sulphuric acid was studied using wood charcoal, animal charcoal, coke, peat, activated carbon, activated sulphur dioxide, coal dust, and colloidal $Fe(OH)_3$. In neutral and acid solutions activated carbon gave the best results. The ferrous sulphate can be removed from the activated material by extraction with hot water.—R. A. R.

Batch Electropolishing. J. F. Kreml. (Steel Processing, 1948, vol. 34, Nov., pp. 589–591, 594). The electrolytic polishing of small parts on a commercial scale is difficult owing to high handling and racking costs. This paper describes a batch method which has been successfully developed for stainless steel screws, bolts, rivets, springs, hooks, and small stampings. The parts are spread on a perforated copper tray with $\frac{1}{8}$-in. holes at $\frac{1}{4}$-in. centres, the bottom of which is coated with a stopping off material; this tray is the anode. The cathode consists of a sheet of expanded metal (stainless steel or other metal resistant to the electrolyte) which is fixed by non-conducting legs to the anode about 2 in. above it; the mesh of the cathode is sufficiently large for the parts to drop through on to the anode tray. Parts which trap gas or have large flat areas on the under side do not polish. The number of parts per unit area of anode must be determined by trial; more than 700 small bolts, rivets and screws (about 33 lb.) were electropolished on a 12 × 12 in. rack with 200 amp. in 10 min. With experimental racks, over 300 lb. of work were polished before the anode had to be replaced.—R. A. R.

PROTECTIVE COATINGS

Throwing Power of Electroplating Solutions. A. Mankowich. (Metal Finishing, 1948, vol. 46, July, pp. 50–54; 1949, vol. 47, Jan., pp. 54–55). Haring and Blum's definition for the throwing power of a plating solution and the Haring cell for measuring it are discussed. This cell is a hard rubber box with slots near each end for two sheet-metal cathodes; a perforated or metal gauze anode is placed in one of two intermediate slots so that one cathode is twice as far from the anode as the other. The ratio of the gain in weight of the near cathode to that of the far cathode is called the "metal distribution ratio" and the definition of throwing powers is "the deviation (in per cent.) of the metal distribution ratio from the primary current distribution ratio." Reasons for the popularity of this definition as well as some criticisms and modifications are given. In the second part of the paper the theory of the Haring and Blum formula is dealt with and it is shown that although it is expressed in empirical terms its validity has been confirmed by the agreement between data obtained with it and those calculated from cathode single potentials, solution resistivities, and current efficiencies. R. A. R.

Laboratory Control of Electroplating Processes. R. P. Marshall. (Metallurgia, 1948, vol. 39, Nov., pp. 11–12). An example is given of the manner in which close co-operation was obtained between the foreman plater and the plant chemist, with details of the procedure adopted to operate a vat and barrel cyanide zinc plant.—R. A. R.

Note on an Examination of the Bendix Method for Determining Coating Thickness on Tinplate. F. W. Salt. (Journal of The Iron and Steel Institute, 1949, vol. 161, Feb., p. 118). Bendix, Stammer, and Carle, have described a method of determining the weight of tin coatings in which the tin is removed by anodically polarizing a tinplate disc in hydrochloric acid containing iodine; porous pots on either side of the disc enclose carbon-rod cathodes. When the electrolysis is continued after the tin has been removed, the apparent coating weight becomes progressively greater. The above authors suggested that this is due to reduction of iodine by ferrous iron dissolved from the specimen. The present author reports experiments which show that the main loss of iodine on continued electrolysis is probably caused by direct combination of iodine and metallic iron at the anode (specimen), the reaction being facilitated by migration of I_3 ions to the anode.—R. A. R.

Review of Methods of Thickness Testing of Electrodeposited Coatings. H. H. Egginton. (Journal of the Electrodepositors' Technical Society, 1948, vol. 23, pp. 191–202). Seven methods of thickness testing of electrodeposited coatings were checked against analysis of a given area which was accepted as standard: Increase in weight due to the deposit; A.R.D. magnetic test; B.N.F. jet test; Mesle's chord grinding test; microscope measurement of the section; micrometer measurement of the increase in section thickness due to the deposit; micrometer measurement of the peeled coat. Mild steel test panels 6 in. by 4 in. by 20 G were chosen (C 0·09%, Mn 0·30%, P 0·04%, S 0·05%). These had been pickled, cold rolled, and close annealed, and before plating, were degreased with white spirit, followed by carbon tetrachloride, and finally pumice brushing. The method of plating is described and details are given of results of the various test methods. The A.R.D. was the best of the non-destructive tests, B.N.F. the best of the partially destructive tests, and the microscope method the best of the completely destructive tests.—J. C. R.

Methods of Testing Thickness of Electrodeposits. I—Effect of Internal Stress on Thickness Determinations by the Jet Method. (Plating, 1948, vol. 35, Sept., pp. 922–924, 966). The jet test for determining the thickness of electrodeposits on steel was applied to stressed and annealed specimens of nickel-plated steel. Internal stress reduces the apparent thickness of the deposit and restressing after annealing has the same general effect. High temperature annealing, which is accompanied by grain growth, raises the apparent thickness much more than low temperature annealing. This type of test must therefore be used with caution and only after it has been calibrated for the particular set of plating conditions. R. A. R.

The Short-Time Testing of Lacquers for Jam Tins. H. Niesen. (Archiv für Metallkunde, 1948, vol. 2, No. 7, pp. 237–248). A report is presented on investigations of the resistance of three German synthetic-resin lacquers on cold-rolled steel panels to attack by distilled water, 2% NaCl. solution, and a 2% NaCl–2% $C_2H_4O_2$ solution. The test procedure was to dip the panels in the lacquer, withdraw them at a rate of 1 cm./15 sec., dry at 180°, 200° and 220 C. for 30 min., and store them for 8 days at room temperature The mechanical properties were then tested in an Erichsen machine and a pendulum impact machine before and after sterilizing for 1 hr. at 100° C., and then immersion of different panels in each of the above solutions. Porosity tests were also made by electrical resistance measurements. The results are given in great detail and prove that this method of testing was a good one for evaluating these coatings. R. A. R.

Porosity of Electrodeposited Metals. III—Measurement of Intrinsic Porosity. (Plating, 1948, vol. 35, Sept., pp. 917–920, 967). Chemical methods are not considered satisfactory for measuring the porosity of electrodeposited coatings as they do not reveal the minute pores believed to exist between the crystals of the deposit, which are referred to as "intrinsic porosity." A new test for this intrinsic porosity is described. The coating is removed from the parent metal and held in a socket between the ends of two tubes. The tubes are connected to two vacuum reservoirs and a mercury-vapour diffusion pump; the apparatus has suitable control cocks and gauges on each side of the diaphragm formed by the peeled coating. After exhausting the apparatus to equal vacuum on each side, a slight overpressure of air is admitted on one side and pressure readings are taken on both sides at frequent intervals. The time taken for the pressures to equalize is an indication of the degree of porosity. The apparatus lends itself to the study of the very earliest stages of corrosion when there is no visible damage and the loss in weight is insignificant. R. A. R.

Investigation of the Effect of High-Frequency Alternating Currents in the Electrolytic Deposition of Chromium. R. Bilfinger. (Archiv für Metallkunde, 1948, vol. 2, No. 4, pp. 131–135). Experiments are described in which high-frequency currents (up to 3500 kilocyles) were superimposed on the plating current applied to commercial CrO_3 + H_2SO_4 plating solutions. No advantage attributable to the superimposed current could be determined; in fact, with the lower frequencies within the range used, there was a marked decrease in the current efficiency of the plating process. Additional tests with nickel and copper plating solutions produced similar results.—R. A. R.

Chromizing Steel Surfaces—Applications. E. Rosen and G. Black. (Metal Finishing, 1948, vol. 46, Dec., pp. 70–71). This article supplements an earlier paper by the same authors. (*see* Journ. I. and S.I., 1949, vol. 161, Jan., p. 68) by giving illustrations of articles which have been chromized.—R. A. R.

Chromizing of Iron and Steel.—A Critical Review. M. Marmach. (Australian Institute of Metals: Australasian Engineer, 1948, Sept. 7, pp. 39–48). Solid, gaseous, and liquid-phase methods of impregnating ferrous metals with chromium are described, and the properties of the impregnated layers and the application of the process are discussed. There are 55 references.—R. A. R.

The Influence of Titanium and Nitrogen on the Galvanising Properties of Iron Sheets. H. Bablik. (Sheet Metal Industries, 1949, vol. 26, Jan., pp. 149–151). The addition of titanium to iron has an indirect influence on galvanizing. The loss in weight and the hydrogen absorbed by the sheet metal during pickling are markedly reduced when the metal contains itanium. When mild steel sheet (C 0·1%) is treated with cracked ammonia for 4 hr. at 700° C. a very spongy structure is formed on the surface and on galvanizing the zinc coating is thick, the iron–zinc layers consisting mainly of the ζ-phase; very small amounts of the δ-phase are present. Nitriding increases the velocity of the dissolution in HCl from 3 to 15 times compared with untreated mild steel. The nitriding produces a very small spongy outer layer; this is, however, sufficient to produce a thick zinc layer and to develop the ζ-phase whilst it prevents the formation of the much more brittle δ-phase.—R. A. R.

Electrodeposited Zinc Coatings. R. Mansell. (Metal Finishing, 1948, vol. 46, Dec., pp. 63–69: Metal Industry, 1949, vol. Jan. 14, pp. 27–30). Methods of electrodepositing zinc coatings are described. Cleaning and pickling are dealt with and the compositions of solutions for cyanide zinc plating, bright zinc plating, and acid zinc plating. Finally, the fluoborate bath is mentioned in which process the following type of bath is used for high-speed plating: Zinc fluoborate 40·2 oz./gal., ammonium chloride 3·6 oz./gal., ammonium fluoborate 4·7 oz./gal., and liquorice 0·134 oz./gal. A *p*H range of 3·5 to 4·0 is maintained with an operating temperature of about 130° F.—R. A. R.

Developments in the Tinning of Cast Iron. H. Warburton. (Mechanical World, 1948, vol. 124, Nov. 19, pp. 579–580). Methods of tinning cast iron, with special reference to two ways of dealing with the graphite, are described. In one, the surface to be tinned is painted with a solution of zinc chloride 9 oz., sodium chloride 2 oz., and water 2 pints. When the metal has been heated to 300° C. a fused salt (82 parts $ZnCl_2$, 18 parts NaCl) is poured on. Finally, molten tin is poured on and wiped over the surface with a wire brush. The second is the nitrate method in which the part is mechanically cleaned and dipped for 15 min. in a bath composed of equal parts of sodium and potassium nitrates at 350° to 400° C. This is followed by washing and pickling in 50% hydrofluoric acid. The same fused-salt treatment is applied and the part is dipped in the tinning pot.—R. A. R.

The Properties and Importance of Cobalt Coatings. A. Kufferath. (Archiv für Metallkunde, 1948, vol. 2, No. 4, pp. 135–136). The literature on the production and properties of electrodeposited cobalt coatings is reviewed.—R. A. R.

Electrodeposition of Cobalt-Tungsten Alloys from a Citrate Bath. W. E. Clark and M. L. Holt. (Journal of the Electrochemical Society, 1948, vol. 94, Nov., pp. 244–252). An aqueous bath suitable for the electrodeposition of cobalt–tungsten alloys, containing about 50% of tungsten, is described. The bath contains cobalt sulphate, sodium tungstate, and citric acid in the approximate mole ratio of 1 : 1 : 1·5, and has a *p*H of about 7, and a temperature of 70° C. A cathode current density of 15 amp./sq. dm. is suitable. Anodes of cobalt or tungsten, of both these metals, or of some inert material may be used.—R. A. R.

Codeposition of Tungsten and Iron from an Aqueous Ammoniacal Citrate Bath. M. H. Lietzke and M. L. Holt. (Journal of the Electrochemical Society, 1948, vol. 94, Nov., pp. 252–261). Experiments were made with three baths with different concentrations of sodium tungstate, and their performance and the effect of changes in certain conditions were studied. The following bath is proposed for the electrodeposition of iron–tungsten alloys: Tungsten as $Na_2WO_4.2H_2O$ 28 g./l.; iron as 50% Fe^{II} and 50% Fe^{III} 2 g./l.; citric acid 66 g./l.; and NH_4OH to *p*H 8. This bath should be at about 70° C., and at a cathode current density of approx. 5 amp./sq. dm. The cathode deposits obtained contain about 50% of tungsten. This ammoniacal citrate bath is also suitable for the deposition of nickel–tungsten and cobalt–tungsten alloys.—R. A. R.

Plastic Protection of Oil Well Drilling Pipe. H. Seymour. (Mine and Quarry Engineering, 1949, vol. 15, Jan., pp. 20–22). Drilling pipes for oil wells frequently fail through corrosion fatigue initiated by corrosion pits on the inside surface forming stress raisers. Examples are given of the successful use of pipes coated on the inside with a phenolic base plastic. The coating is applied by filling the pipe in a vertical position and allowing the plastic to drain off at the controlled rate of 1 ft. in 12 to 15 sec. After drying in air for 30 to 60 min., the pipes are heated in a gas-fired oven at about 450° F. for 8 to 12 min. to set the coating.—R. A. R.

Rustproofing Vanguard Body. (Machinist, 1949, vol. 92, Jan. 1, pp. 1149–1152). The continuous automatic cleaning,

phosphate coating and primer painting plant, installed at the Castle Bromwich factory of Fisher and Ludlow Ltd., is described. The motor-car bodies (of the 'Vanguard') are treated in this plant, the unique feature of which is that these bodies, each weighing 9 cwt., are slowly rotated during their passage through the various sprays and dip tanks to ensure that every part is treated.—R. F. F.

Hard-Facing Techniques. M. Riddihough. (Welding, 1948, vol. 16, Oct., pp. 428–432; Nov., pp. 477–480). Various processes for hard facing are described, including the use of oxy-acetylene for fusion deposition and bronze welding, the metallic arc and atomic hydrogen arc methods, the spraying of a powdered hard-facing alloy followed by fusion welding, and powder-weld deposition by feeding the powder through an oxy-acetylene flame.—R. A. R.

New Metallizing Technique "Homogenizes" Alloy Coatings to Eliminate Porosity. J. A. Looney. (Petroleum Processing, 1946, vol. 1, pp. 290–292: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8764). Refinery equipment can be protected by a new metal-spraying process which eliminates porosity and is more resistant to corrosion and abrasion than conventional coatings. Any metal capable of being formed into wire or rod can be sprayed to any desired depth. The coating will not peel off and can be heat-treated. The coating equipment is portable so that large vessels can be coated.

Flame-Spraying Corrosion Resistant Linings. H. W. Greenwood. (Industrial Chemist, 1948, vol. 24, Nov., pp. 743–745). The economic advantages of flame-spraying with the Schori pistol are pointed out with special reference to the protection afforded by the synthetic materials Thiokol and Polythene, as well as by sprayed bitumen.—R. A. R.

Protection of Steel by Coatings Permeable to Water. F. J. Hermann. (Verfkroniek, 1948, vol. 21, pp. 156–161: Chemical Abstracts, 1948, vol. 42, Oct. 20, col. 7996). The necessary properties of paints for the protection of steel including Pb_3O_4, iron oxide, $ZnCrO_4$ paints, and paints containing metallic zinc pigments, are discussed.

Rapid Examination of the Rust-Preventing Properties of Paints. J. van Loon. (Verfkroniek, 1948, vol. 21, pp. 182–185: Chemical Abstracts, 1948, vol. 42, Nov. 10, col. 8486). This is a review of all existing methods for this purpose and a detailed discussion of all factors which, when combined, would give the ideal method.

The Interpretation of Fouling Samples from Ships. M. W. H. Bishop, K. A. Pyefinch, and Molly F. Spooner. (Journal of The Iron and Steel Institute, 1949, vol. 161, Jan., pp. 35–40). The kind of results than can be obtained, and deductions that can be drawn, from a set of samples of the fouling from a ship, are described. Acorn barnacles, tube-worms, and oysters are the major animal fouling organisms, the green seaweed *Enteromorpha* and the branched brown seaweed *Ectocarpus* are the major plant forms. Examination of the samples, together with counts and measurements of some of these major fouling organisms, give some idea of the sequence of fouling settlement. Correlation of this sequence with the route makes the construction of a fouling history possible, an example of which is given. The reconstruction of a fouling history enables an estimate of the length of 'life' of the anti-fouling paint to be made. The deliberate provision of non-toxic areas would help considerably in forming this estimate.

Many reconstructions of fouling histories are tentative and a high level of certainty will be reached only when fuller biological information is available. However, it may be concluded that the average service period is considerably greater than the average length of life of the anti-fouling compositions used. It is emphasized that the absence of fouling on dry-docking is not valid evidence of the effectiveness of the anti-fouling composition throughout the voyage.

Shrinkage and Deterioration of Paint Coatings. W. Koenig. (Paint, Oil and Chemical Review, 1948, vol. 3, Sept. 16, pp. 15, 43–46; Sept. 30, p. 19: Railway Engineering Abstracts, 1948, vol. 3, Dec., pp. 314–315).

POWDER METALLURGY

Production of Electrolytic Iron Powder. G. Wranglen. (Jernkontorets Annaler, 1948, vol. 132, No. 12, pp. 501–516). [In Swedish]. Electrolytic metal powders can be produced either by direct deposition at the cathode or by grinding of a coherent deposit. In the case of iron the latter method is the simplest and cheapest, and although there are many patents dealing with the direct deposition of iron powder, there is no evidence that this method is in commercial use. In the investigation presented in this paper both methods have been tried, and detailed information is given for the conditions of electrolysis in both cases.

For the direct deposition of iron powder the following conditions are recommended: 15 g./litre Fe as $FeCl_2$, 100 g./litre NH_4Cl, 50° C., *p*H 7 (2–3 g./litre of the iron as hydroxide), 100 amp./sq. ft. The current efficiency is 95%. With an electrode distance of 1·2 in. the cell voltage is 2 V., which means a power consumption of about 1 kWh./lb. of iron. The formation of powder on the cathode in this case is due to the precipitate of hydroxide in the cathode film. For the production of a coherent but brittle deposit, which can be easily comminuted to a fine powder, the following conditions are recommended: 60 g./litre Fe as $FeCl_2$, 50 g./litre NH_4Cl, 60° C., *p*H 5–6, 30 amp./sq. ft. With an electrode distance of 1·6 in. the voltage is 0·9 V. and the power consumption is about 0·5 kWh./lb. of iron. In both cases soluble anodes of mild steel have been used.

The influence of the structure of the deposited iron on the shape of the powder particles is discussed. The powdery deposits obtained on the cathode consist of arboraceous (treed) formations, which, after breaking up, will give a powder of rather equi-axial particles. The fibrous structure of the normal deposit gives long needle-like particles after grinding, which are undesirable from a powder-metallurgical point of view. Three methods are proposed for modifying the fibrous structure so that more equi-axial particles will be obtained after grinding. This may be done by cutting off the long acicular crystals with intermediate layers of oxide or another metal, or by dispersing in the electrolyte an electrically conducting substance, as a finely divided metal or carbon powder, which will change the structure from a fibrous one to an irregular mosaic structure.

In the discussion of the industrial application of the results obtained, special attention is given to the anode material and the anode process. Although scrap iron is intended as raw material, the use of insoluble anodes is considered as less promising for various reasons than a process on the basis of scrap iron as soluble anodes, which is described in some detail. An example is to be found in the electrolytic detinning of tinplate scrap. The scrap iron is fed into baskets of wood, faced with filter-cloth and lined with graphite or Duriron plates, which serve to conduct the current to the scrap. This principle has been successfully applied by two small plants in Sweden.—J. K.

The Influence of the Surface Structure of Individual Powder Particles in the Production of Powder Metal Components. A Discussion of Fundamental Principles. S. J. Garvin. (Murex Review, 1948, vol. 1, No. 2, pp. 17–32). The fundamental laws which control the formation of synthetic compacts are explained and discussed. The importance of factors such as various types of surface roughness, skins of impurities and their removal, and atomic mobility at surfaces is demonstrated. The great diversity of possible reactions is pointed out, but it is shown that the main types of bonding processes such as adsorptive adhesion, movement of atoms in the lattices, grain-growth during fritting, solubility reactions, and equilibria during sintering suffice to describe the various phenomena.—R. A. R.

The Classification of Powder Particle Size by Sieve. T. Burchell. Murex Review, 1948, vol. 1, No. 2, pp. 33–38). These notes explain the system of classification of the size of small particles by sieve. Tables are also presented comparing the British and German standards, the Institution of Mining and Metallurgy standards and the Tyler standards of sieve aperture widths and wire diameters. Precautions to be taken in selecting samples for sieve tests and when specifying particle size by "passing x mesh, and standing on y mesh" are pointed out.—R. A. R.

Powder Metallurgy in Japan—Post-War Developments K. Ogawa. (Powder Metallurgy Bulletin, 1948, vol. 3, Nov., pp. 128–129). A brief summary is given of work done since 1945 on powder metallurgy at the Kyoto University laboratories. A definite temperature range of plastic flow for silver, copper, and iron has been observed, and better results are obtained in hot pressing by reducing the pressure within this temperature range.—R. A. R.

Sintering Furnaces and Atmospheres. H. C. Bostwick. (Industrial Heating, 1948, vol. 15, Oct., pp. 1664–1678,

1831, 1832). Conveyor furnaces and generators for protective atmospheres for sintering parts made by powder metallurgy are described and illustrated.—R. A. R.

Notes on the Course of the Reaction in the Process of Sintering Iron Powder. H. Bernstorff. (Archiv für Metallkunde, 1948, vol. 2, Mar, pp. 103–106). Tensile specimens were prepared by sintering and pressing ' D.P.G.' iron powder which had been annealed in hydrogen. These were made by pressing at 6 tons/sq. cm. and sintering for 2, 4, 6, 8, and 10 hr. at 850°, 1000°, 1150°, and 1300° C. in hydrogen. The changes in tensile strength and elongation with sintering time and temperature are shown by curves. Both these properties are at minimum values at points between 2 and 6 hr., but the dip in the curves becomes less with increasing temperature. The cause of these minima is not a loosening of the structure by an increase in grain-growth, but is to be found in a transition from one kind of reaction mechanism to another, as has been explained by G. F. Hüttig.—R. A. R.

Application of the Theory of Diffusion to the Formation of Alloys in Powder Metallurgy. P. Duwez and C. B. Jordan. (American Society for Metals, Oct. 1948, Preprint No. 37). A simple theoretical discussion is first given, by means of which it is possible to predict approximately the time and temperature required for complete homogenization by diffusion of a mixture of two metal powders. The theory is first developed for one-dimensional diffusion in a stack of interleaved thin sheets of two metals. With the aid of an analysis by Weinbaum of diffusion in a simple model of a mixture of powders, it is then shown that the time and temperature of homogenization can be predicted for a three-dimensional case. The method involves only consulting a pair of charts which are given : no calculations are required. Experimental investigations using copper and nickel alloys are described. Results were compared with those predicted by theory : the agreement was qualitatively correct and quantitative deviations were considered to be understandable in view of the range of experimental variables involved.—J. C. R.

Metal Powder Parts Replace Those Produced by Other Methods. H. R. Clauser. (Materials and Methods, 1948, vol. 28, Nov., pp. 64–68). Six examples are described of parts which have been successfully made by powder metallurgy. They are helical gears, brush holders, fuse washers, small double-slide bearings, and heads for electric razors.
R. A. R.

PROPERTIES AND TESTS

Review of the Congress on the Physics of Metals. M. J. Druyvesteyn. (Metalen, 1948, vol. 3, Nov., pp. 49–58). [In Dutch]. An international congress on the physics of metals was held at Amsterdam from the 12th to the 17th July, 1948. This review contains brief summaries of the papers.
R. A. R.

The Contribution of Modern Physics to Metallurgy. F. Seitz. (Journal of Applied Physics, 1948, vol. 19, Nov., pp. 973–987). The contributions of physics to metallurgy are reviewed under the headings : Atomic structure, lattice structure, electrical conductivity, difference between metals and non-metals, source of metallic cohesion, magnetic properties, migration of atoms in metals, and mechanical properties of metals.—R. A. R.

The Choice of a Special Steel according to Its Use. B. Hedde D'Entremont. (Machines et Métaux, 1948, vol. 32, Dec., pp. 412–420). The factors affecting the mechanical properties of steels are discussed. These include : Method of production and working, alloying elements, structure, heat-treatment and corrosion.—R. F. F.

25-Ton Universal Testing Machine. (Engineering, 1948, vol. 166, Dec. 17, p. 595). A brief description is given of a 25-ton testing machine with which tensile, compression, beam, shear, and bending tests can be made ; general pressing operations requiring precision control can also be performed. Power is provided by a hydraulic pump operated by a hand lever.—R. A. R.

Twelve-Ton Testing Machine, Type IM-12. I. V. Kudryavtsev. (Zavodskaya Laboratoriya, 1947, vol. 13, p. 892 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8748). The machine is intended for static tests of tensile strength at normal and high temperature for loads up to 12 tons ; it is equipped with an automatic recorder of load-deformation curves, it is 425 mm. wide, 1400 mm. long, and 1400 mm. high ; it is placed on a brick base 500 mm. wide, 900 mm. long, and 600 mm. high.

A Method for Testing Brittle Materials. L. V. Abanov. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., p. 1400). [In Russian]. The method briefly described for testing the mechanical properties of brittle substances can also be used with plastic materials such as untempered steel.—S. K.

A Method of Testing Structural Steels for Brittleness. W. Hummitzsch. (Schweisstechnik, 1948, vol. 2, Nov., pp. 134–136). The notched-bead slow bend test for weldability developed by A. B. Kinzel is described. (*See* Journ. I. and S.I., 1948, vol. 158, Mar., p. 410).

Upper Yield Point : Occurrence in Bending Tests and Signification. C. Benedicks and R. Skorski. (Hutnik, 1948, vol. 15, No. 2, pp. 49–53). [In Polish]. This paper describes the investigation, the results of which have already been reported in *Nature* (*see* Journ. I. and S.I., 1947, vol. 157, Dec., p. 644).

Micro- and Macro-Deformations of Metals and Alloys under Longitudinal Impact Loads. G. Welter. (Metallurgia, 1948, vol. 38, Sept., pp. 287–292 ; Oct., pp. 328–330 ; vol. 39, Nov., pp. 13–17). An investigation of the dynamic, elastic, and plastic properties of metals and alloys under increasing longitudinal impact loads is reported. After each dynamic loading the effect was checked by special shock-proof instruments which could measure very small permanent deformations in the longitudinal axis of the specimens. Aluminium, Duralumin, magnesium alloy 57S, mild steel, and a medium carbon steel were investigated and their dynamic elastic limit for permanent sets of 0·003% and 0·01% were determined. A 10-fold higher energy was necessary to reach the 0·01% elastic limit for the medium carbon steel than for aluminium. Mild steel, because of its yield point, showed during the second loading cycle a 20% lower dynamic elastic limit than the unstretched virgin material. Specimens struck with the pendulum hammer had distinct non-axial deformation because the hammer described an arc ; a form of hammer which dropped vertically was therefore devised. The Bauschinger effect was investigated with the drop hammer apparatus and was rather pronounced for all five materials, especially for the magnesium alloy.—R. A. R.

The Construction of Ballistic Testing Machines. G. P. Zaitsev. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1356–1365). [In Russian]. The theory of ballistic testing machines (*i.e.*, those in which the specimen, situated on the bob of a heavy pendulum is struck by a lighter bob) is developed together with the theory of the physical pendulum ; and on this basis estimates are made of the parasitic energy losses in ballistic and ordinary testing machines. These losses are shown to be responsible for the large divergencies in values for the impact elasticity of a given substance when determined on different testing machines. Most of these losses take place through the elastic deformations occurring in the parts of the machine, the loss of energy through the base of the machine being negligible. On these grounds it is concluded that the ballistic machine has no advantages in mechanical testing. The principle of the evaluation of the impact elasticity of slightly plastic metals is developed.—S. K.

Apparatus for Recording the Speeds of the Deformation of a Metal by Impact-Load. V. F. Loshkarev. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1401–1403). [In Russian]. An account is given of a method for the study of the process of plastic deformation of metals under impact loads. A beam of intense light, interrupted 2303 times/sec. by a rotating disc with holes in it, passes through a special aperture in the drop-weight of the testing machine and enters a camera containing a photo-sensitive surface fixed on a drum which is rotated at 6000–10,000 r.p.m. by an air turbine. From the pattern obtained on the sensitive surface, the deformation process can be elucidated. The construction of the apparatus is briefly described and details are given of its operation for various magnitudes of deformation. An example is given of the pattern as recorded.—S. K.

A New Material for Three-Dimensional Photoelasticity. M. M. Leven. (Proceedings of the Society for Experimental Stress Analysis, 1948, vol. 6, No. I, pp. 19–28). A new material of the styrene-alkyd class of resins, known as "Fosterite" with properties for 'frozen stress' tests superior to those of any other known material has been developed. Cylinders of

this resin 6 in. in dia. and 3 ft. long have been successfully cast. Characteristic curves showing the variation of physical and optical properties with temperature and duration of load for this class of resin are presented, and methods of use are proposed.—R. A. R.

Long-Time Electric Strain Gauge Measurements on Concrete Reinforcing Rods at the Packard Proving Grounds Test Track. F. L. Moncher, H. R. Lissner, and C. H. Lipson. (Proceedings of the Society for Experimental Stress Analysis, 1948, vol. 6, No. I, pp. 29–34). A description is given of the methods used to attach electric strain gauges to hooked reinforcing rods used in the construction of a concrete testing track for the Packard Motor Car Co., Utica, Mich. The protection of the gauges from weather and from injury when laying the rods in the concrete is dealt with and some results are reported.—R. A. R.

Some Simplifications in the Numerical Solution of Laplace's Equation with Special Applications to Photoelasticity. M. M. Frocht. (Proceedings of the Society for Experimental Stress Analysis, 1948, vol. 6, No. I, pp. 39–43). Laplace's equation furnishes one method of determining the sum of the principal stresses at a point in two-dimensional problems from photoelastic data. A method is proposed for determining initial values for the numerical solution of the Laplace equation for a harmonic function with known boundary values. In this, the Linear "Rosette Method," several straight lines are drawn through a given point in the form of a rosette. Each line is viewed as a taut string the slope of which is determined by the boundary values of the harmonic function. The initial value of the function at a given point is taken as the arithmetic mean of all the ordinates over the given point. The effect of this approach is to reduce markedly the number of iterations necessary to attain approximate convergence, thereby saving much time and labour.—R. A. R.

A Direct Coupled Amplifier for Recording Dynamic Strain. W. R. Mehaffy, J. N. van Scoyoc, and D. S. Schover. (Proceedings of the Experimental Society for Stress Analysis, 1948, vol. 6, No. I, pp. 44–54). An amplifier for electric strain-gauge measurements is described. It is of the balanced direct-coupled type in which the drift has been minimized by careful design of the circuits and mechanical arrangement. It has the advantage of covering a broad range of frequency.—R. A. R.

A Photoelastic Study of Stresses in U-Shaped Members. J. B. Mantle and T. J. Dolan. (Proceedings of the Society for Experimental Stress Analysis, 1948, vol. 6, No. I, pp. 66–73). Photoelastic stress analysis was employed to determine the effect on maximum stresses produced by changing the eccentricity of load position and by altering the proportion of members having approximately a **U** shape.—R. A. R.

The Photoelastic Laboratory at the Newport News Shipbuilding and Dry Dock Company. B. R. Lee, R. Meadows, jun., and W. F. Taylor. (Proceedings of the Society for Experimental Stress Analysis, 1948, vol. 6, No. I, pp. 83–110). The instruments, equipment, and methods for photoelastic stress analysis used by the Newport News Shipbuilding and Dry Dock Company are described in detail. The faults and advantages of different types of equipment and reasons for the final selection made are given.—R. A. R.

The Equilateral Fleximeter. G. Brewer. (Proceedings of the Society for Experimental Stress Analysis, 1948, vol. 6, No. I, pp. 123–130). A description is given of the Equilateral Fleximeter for determining the state of stress due to bending moments alone at any given point on a structure. When used in conjunction with an equilateral strain gauge rosette the axial stresses and the stresses on the inaccessible side of a plate can be determined from external measurements. The instrument comprises three standard Statham dynamometers, with certain electrical modifications, so mounted that each dynamometer pin follows changes in chord height of the plate in a plane parallel to the base of the dynamometer. Each dynamometer is mounted in a plane at 60° to its neighbour, thus enabling the rise in chord height to be measured in three planes. The principal stresses resulting from bending can be calculated from the data obtained. R. A. R.

Brittle Features in Mild-Steel Plates—III. (Engineering, 1948, vol. 166, Nov. 19, p. 497; Nov. 26, pp. 508–509; Dec. 3, pp. 532–533; Dec. 10, pp. 557–558; Dec. 17, pp. 580–581; Dec. 24, pp. 605–606; Dec. 31, pp. 628–630). Part III of this series presents the discussion on the nine papers at the Conference on Brittle Fracture in Mild Steel Plates held at Cambridge in October, 1945. (*See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 300).—R. A. R.

Diagrams of Extension and Compression with Dynamic Action of Forces. P. G. Kirillov. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1377–1379). [In Russian]. A new, indirect method for the determination of speed of deformation, acceleration, and force is proposed. The method is based on the photographic recording of the path traced by a periodically oscillating spot of light impinging on a plate the motion of which corresponds to that under investigation; it offers the advantage of an inertialess recording system. Examination of the line obtained on the plate enables the characteristics of the motion to be calculated, the frequency of oscillation of the light-spot being known. Examples of results obtained by this procedure are shown, and its possible applications to the study of various moving systems are discussed.—S. K.

A Simple Process for Measuring Viscosity at High Temperatures. A. Knappwost. (Zeitschrift für Metallkunde, 1948, vol. 39, Oct., pp. 314–318). This method of determining viscosity is based on measurement of the torsional oscillations of a small suspended cylindrical crucible containing the molten metal or liquid. The viscosity can be calculated since there is a direct relationship between the logarithm of the decrement of the oscillations, and the viscosity and density of the liquid. The apparatus consists of a crucible 3 cm. inside dia. × 8 cm. high, held in a rigid refractory frame which extends above the electric furnace surrounding it. The frame is brazed to a torsion wire about 60 cm. long. The initial amplitude is 20° to 30°, and the decrement is measured by a beam of light passing over a scale at 3 m. radius from the wire.—R. A. R.

Symbols and Nomenclature for Fatigue Testing. (A.S.T.M. Bulletin, 1948, Aug., pp. 36–37). Suggested symbols and nomenclature for fatigue testing are given.—J. C. R.

Effect of Surface-Active Substances on the Fatigue of Steel. Sh. Ya. Korovskiĭ. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 59, pp. 1149–1451: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8748). Specimens of steel were subjected to fatigue tests in (1) air, (2) redistilled petrolatum, (3) petrolatum + 0·2% oleic acid, and (4) (4) petrolatum + 0·3% cetyl alcohol. The number of cycles required for destruction at a given load was less for (3) and (4) than for (1) and (2), the decrease being greater for quenched and tempered steel than for normalized steel. When specimens were shot-peened prior to testing, the difference in medium (4) was considerably lessened, and with nitrided specimens no difference was found. It was concluded that the decrease in fatigue strength in certain media was an adsorption rather than a corrosion phenomenon.

Trapped Stresses. H. O. Fuchs. (Machine Design, 1948, vol. 20, July, pp. 114–118, 178). The manner in which intentionally produced trapped or residual stresses can increase the service life of parts subjected to fatigue and other external loads is explained. The examples cited include inducing compressive stresses in a gun barrel bore, prestressing leaf springs and shot-peening axles. The methods by which the stresses are induced are briefly described.—R. A. R.

Corrosion-Fatigue of Steel under Asymmetric Stress in Sea Water. A. J. Gould. (Journal of The Iron and Steel Institute, 1949, vol. 161, Jan., pp. 11–15). The severity of corrosion fatigue in sea water under reversed stress with superimposed tensile stress depends on the stress-range, but is found to be almost independent of the mean stress of a cycle, provided that this is not excessive. The result was obtained on polished specimens, scale-covered specimens, and specimens descaled by pickling. The endurance as measured on a push-pull machine is roughly five times as great as that measured on a rotating-beam machine for the same materials and stresses. In well-aerated sea water, the test-piece breaks at its most slender section. In the absence of aeration, fracture usually occurs about 1 cm. below the water line, even though the stress here may not be maximal.

Failure of Railway Materials. Fracture in Rails and Locomotive Parts. B. R. Nijhawan. (Iron and Coal Trades Review, 1949, vol. 158, Jan. 7, pp. 1–5). A brief illustrated account is given of the occurrence of transverse fissures in railway rails and tyres and of fatigue failures in locomotive parts.—J. C. R.

Metallurgical Aspects of Mining Gear Failures. R. Jeffrey. (Institution of Mining Engineers, Jan. 1949: Iron and Coal Trades Review, 1949, vol. 158, Jan. 21, pp. 123–129).

The author reports an investigation into the causes of breakage of haulage, winding and other mining gear. The causes of failure are classified and analysed.—J. C. R.

Nomogram for Determining Hardness of Steel from Heat Treating Data. A. P. Gulyaev. (Zavodskaya Laboratoriya, 1947, vol. 13, pp. 888–889 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8746). Construction of the nomogram was based on the following premises ; (1) With rising temperature of tempering the hardness drops ; for steels of varying carbon content (0·11–1·18%) the intensity with which the hardness drops is the same with rising temperature of tempering within the range 300–650° ; (2) hardness plotted against duration of tempering on semilog paper for the interval 1 min. to 10–25 hr. is a straight line. On the basis of data for 0·35% carbon steel the nomogram was constructed showing hardness as a function of carbon content and of tempering temperatures 350°, 450°, 550°, and 650°. The use of the nomogram is explained.

Device for Checking the Performance of the Rockwell Hardness Tester. T. A. Vvedenskiĭ. (Zavodskaya Laboratoriya, 1947, vol. 13, p. 891 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8748). The device consists of a **U**-shaped arch of spring steel within which is a holder on screws and balls and an indicator fixed to the end of the holder. The holder can have two positions—for a transfer of 2 : 1 and 5 : 1. The device is placed on the table of the Rockwell tester. Pressure of the spindle causes deformation of the arch which is recorded by the indicator. The device is first checked with loads.

The Effect of Internal Stresses on Hardness. P. Blain. (Sheet Metal Industries, 1949, vol. 26, Jan., pp. 135–136). Methods of measuring the hardness on each side of a steel disc, deformed in a fixture which puts one side in compression and the other in tension, are described. The difference cannot be measured accurately by penetration methods, but good results are obtained by determining the maximum load which can be applied with a 10-mm. ball without leaving an indentation. The ratio of the hardness of the compressed and extended surfaces of a steel disc can vary between 5 and 1 according to whether the metal is in compression or tension of the order of 165 kg./sq. mm. in the region tested.—R. A. R.

Wear Resistance of Wire for Wire Rope. R. S. Brown. (Wire and Wire Products, 1948, vol. 23, Nov., pp. 1037–1047, 1061, 1062). The influence of manufacturing methods on the wear of wire ropes has been studied using a specially designed machine in which short straight lengths of wire were clamped to a solid base which was oscillated with a stroke of 1 in. at 33 cycles/min. Wearing nibs of tungsten carbide brazed to steel supports carried on a pivoted arm bear upon the specimen under an adjustable load. Keeping the degree of cold work and drawing temperature constant, the influence of carbon content and patenting process were studied. To produce tensile strengths of 120 tons/sq. in., patenting in lead at 500°, and 590° C., and in air required carbon contents of 0·65%, 0·70%, and 0·80% respectively. The very high carbon content of air-patented wire yields a better wear resistance than 0·70% carbon steel patented in lead at 590° C., but inferior results to the 0·65% carbon steel patented in lead at 500° C. Cooling in lead at 500° C. therefore induces a marked increase in wear resistance. Wear tests on wires of five carbon contents in the 0·47–0·81% range, with reductions in drawing of 71·5%, 75%, 80%, 85%, and 88% showed the comparative unimportance of heavy drawing on the wear properties. With the lower carbon steel lead-patented wire the cold worked film has poor strength and is being continuously removed in large thin flakes by the wear, but with a high carbon wire a relatively thick cold worked layer, which is highly resistant to further wear, is built up.—R. A. R.

The Electron Theory of Metals. C. W. Orr. (Australian Institute of Metals : Australasian Engineer, 1948, Sept. 7, pp. 52–58). The author explains the structure of the atom, the application of the electron theory to metals and to alloy structures, and the electrical and magnetic properties of metals in terms of the electron theory.—R. A. R.

Modern Theories of Magnetism and Their Application. L. Néel. (Société Française de Métallurgie, Oct. 10, 1947 : Revue de Métallurgie, Mémoires, 1948, vol. 45, Nov., pp. 475–480). The author discusses recent advances in the theory of ferromagnetism and shows how they have contributed to progress in practical applications.—A. E. C.

Contribution to the Study of the Thermo-Electric Power of Metals. C. Crussard and F. Aubertin. (Société Française de Métallurgie, Oct. 10, 1947 : Revue de Métallurgie, Mémoires, 1948, vol. 45, Oct., pp. 402–410). The results of a study of the effects of cold work on the thermoelectric power of certain pure metals and of quenching, precipitation-tempering and recrystallization on the same property of impure metals are presented and discussed. Most of the materials examined are non-ferrous, but the effect of heat-treatment on the thermoelectric power of iron, with or without previous cold work, is touched upon.—A. E. C.

Some Aspects of the Physics and Testing of Electrical Sheet Steels. N. F. Astbury. (Journal of the Junior Institution of Engineers, 1948, vol. 59, Oct., pp. 1–20). The author surveys the structure, magnetic properties, and methods of testing electrical sheet steels. Magnetization and its relation to structure are explained. Small additions of carbon and sulphur adversely affect hysteresis losses without affecting eddy losses, whilst larger additions of silicon or aluminium will affect eddy losses without appreciably affecting hysteresis losses.

The investigation of structure by X-ray back-reflection diagrams is described and explained. It is shown how Young's modulus in various directions can be obtained, how this varies with the direction of rolling, and how the distribution of crystal directions in the aggregate can be estimated. The structure within grains can be delineated by putting a very thin film of grease or lacquer on the published surface and spreading a colloidal suspension of iron oxide on this ; examples of patterns on silicon iron are shown.

As it is important to be able to determine very low contents of carbon and sulphur, an improvement to the combustion method has been developed in which the change in the electrical conductivity of the solution absorbing the CO_2 or SO_2 is measured with A.C. in the audio-frequency range, the conductivity being directly related to the weight of carbon or sulphur involved.—R. A. R.

Electrical Sheet Steels. F. Brailsford. (Journal of the Institution of Electrical Engineers, 1948, vol. 95, Part I, Dec., pp. 522–531). The development of the theory of ferromagnetism is briefly reviewed and some of the more outstanding relevant laboratory investigations are discussed, including work on the effect of impurities, the magnetic properties of single crystals, on hydrogen annealing and on heat-treatment in a magnetic field. The development and properties of the cold-rolled silicon steels for transformers are then reviewed, as well as advances in the hot-rolled steels. Cobalt–iron alloys with magnetic saturation values higher than for iron are discussed. Finally, the development of the nickel–iron alloys is traced, concluding with the most recent advances in this field.

Magnetization of Thin Ferromagnetic Films. A. Drigo and M. Pizzo. (Nuovo Cimento, 1948, vol. 5, pp. 196–206 : Chemical Abstracts, 1948, vol. 42, Oct. 20, col. 7587). Theories of magnetism predict that the properties of thin films should differ from those of massive samples. Experiments with thin films of iron, cobalt, and nickel show that the characteristics of the magnetization curve vary with film thickness. Barkhausen discontinuities disappear at a thickness of $1·2 \times 10^{-5}$ cm. for cobalt, $0·8 \times 10^{-5}$ cm. for nickel, and $1·3 \times 10^{-5}$ cm. for iron.

Permanent-Magnet Materials. D. A. Oliver and D. Hadfield. (Journal of the Institution of Electrical Engineers, 1948, vol. 95, Part I, Dec., pp. 531–539). Developments in permanent-magnet materials since 1936 are reviewed. Tables show analyses and magnetic properties of permanent-magnet materials available prior to 1937, of anisotropic permanent-magnet alloys available since 1937, of easily machined permanent-magnet materials available since 1937, and of permanent-magnet materials made from powders since 1930.—J. C. R.

Permanent Magnet Stability. R. J. Studders. (Product Engineering, 1948, vol. 19, Nov., pp. 129–133 ; Dec., pp. 113–118). The effects of changes in structure and temperature, and of mechanical shock, impact, vibration, and reluctance changes in the magnetic circuit, on the stability of permanent magnets, particularly the Alnico alloys, are discussed. The remanence of a fully magnetized magnet increases as its temperature is decreased below room temperature ; and the initial remanence is restored when the

temperature returns to normal. On heating, the remanence decreases, but it is not entirely restored on cooling. Where it is desired to maintain an air-gap flux as constant as possible a magnetized magnet may be stabilized against external factors by subjecting it a number of times to conditions slightly more severe than those to be expected in service. Such treatment leaves the magnet in a state of maximum stability, and removes that part of any change of flux which is not reversible with the external influence.—R. A. R.

Permanent Magnets from Pure Iron Powder. R. Steinitz. (Powder Metallurgy Bulletin, 1948, vol. 3, Nov., pp. 124–127). Some particulars are given of the methods employed by the Société d'Electro-Chimie, d'Electro-Métallurgie, et des Aciéries Electriques d'Ugine, at Grenoble, in the manufacture of permanent magnets from iron powder of a size between 0·1 and 0·2 micron. Although pure iron in the cast or rolled state is magnetically soft, particles below a certain critical size will form "single domain" particles and therefore have permanent magnetic properties. This powder is made by dissolving iron scrap in formic acid at elevated temperature and precipitating the formate during cooling; the formate is then decomposed and reduced in hydrogen at a temperature not above 400° C. This powder must be covered by a liquid in the cooling zone of the furnace before removal. The powder is pressed while still wet at 30 to 50 tons/sq.in. The magnets are mechanically weak but their strength can be increased four to five times by heat-treatment between 300° and 400° C., although this slightly decreases the coercive force and increases the residual magnetism.—R. A. R.

Resin Bonding of Silicon Steels in Electrical Laminated Cores. S. B. Ashkinazy and J. J. Preisler. (Product Engineering, 1948, vol. 19, Nov., pp. 85–89). Electrical factors underlying the design of magnetic cores are reviewed, the properties of silicon steel used for core laminations are discussed, and the methods adopted by the Sperry Gyroscope Company for bonding laminations with synthetic resin are described. R. A. R.

The Specific Heat and Resistivity of High-Purity Iron up to 1250° C. P. R. Pallister. (Journal of The Iron and Steel Institute, 1949, vol. 161, Feb., pp. 87–90). In order to obtain the true specific heat of high-purity iron in a state of thermal equilibrium, a method is adopted in which the observed temperature increments are small, and the intervals between observations are occupied by slow heating or cooling of the annealed specimen. For this purpose the sample rod is mounted in an evacuated electric furnace and maintained at any desired temperature up to 1250° C. Then a momentary electric current is passed, heating the rod through 1 or 2° C. Radiation losses to the furnace tube are substantially reduced by the employment of a suitable concentric shield, electrically in series with the rod, so that the passage of the current heats them both coincidentally in magnitude and time. Electrical resistivity measurements, which are required for the evaluation of the energy delivered to the rod, are interspersed among the observations over the whole range of temperature.

Ultrasonic Material Testing and other Applications. (British Intelligence Objectives Sub-Committee, 1949, Final Report No. 1679: H.M. Stationery Office). This report, by D. O. Sproule, contains the information gained during his search for any new work in Germany in the general field of ultrasonic research. Many different workers had obtained suggestive results pointing to the possibility of industrial application of supersonics to emulsification, precipitation, preparation of fine-grain alloys, and many similar applications, but there were very few examples of actual use on an industrial scale. Many German technical papers on ultrasonics are reproduced in full.—R. A. R.

Supersonics *versus* Radiography. H. R. Isenburger. (Metal Progress, 1948, vol. 54, Sept., p. 318). The defects in a weld shown up on the reflectoscope screen of a supersonic apparatus are compared with those visible on a radiograph of the same area. One method is shown to supplement the other.—R. A. R.

The Application of Ultrasonics in Engineering and Physics. S. Ya. Sokolov. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1328–1335). [In Russian]. The general relationships between the absorption of waves of ultrasonic frequency and the nature of the absorbing medium are discussed, and experiments are described in which this absorption by specimens of iron of different grain-sizes was studied with frequencies of 18×10^6 and 4×10^6. The evolution of ultrasonic defectoscopy is traced from 1927, and the present technique, in which an image of the defect is obtained on the screen of a cathode tube with the aid of the "ultrasonic microscope," is outlined. The measurement of the depth of the hardened layer in steel by ultrasonic methods is dealt with, an approximate and an accurate procedure being given. The article concludes with a sketch of the uses of ultrasonic techniques for the study of chemical kinetics and crystals.—S. K.

Damping Capacities of S.A.E. 1020 and 2320 Steels. L. Tarnopol and J. R. Morgan. (Transactions of the Indian Institute of Metals, 1948, vol. 1, June, pp. 55–69). The damping capacity of several 0·20% carbon steels and 3·5% nickel steels in relation to the maximum fibre stress after various annealing and carburizing treatments was studied. Machining increased the damping capacity, whilst subsequent ageing or annealing decreased it. The changes in damping capacity at high stress values could be accounted for by assuming that plastic slip was an important factor.—R. A. R.

Internal Damping in Metals. H. C. den Daas. (Metalen, 1948, vol. 3, Dec., pp. 73–77). [In Dutch]. The physical origins of the internal friction in metals, as far as they are known to-day, are reviewed. They can be divided into diffusion effects and viscosity effects.—R. A. R.

The Use of X-Rays in Industry. K. A. Metcalfe. (Australian Institute of Metals: Australasian Engineer, 1948, Oct. 7, pp. 38–45). A comprehensive review is presented of the industrial uses of X-rays and gamma-rays. The equipment and techniques are described. There are 29 references. R. A. R.

An Extruding Die for Powdered X-Ray Diffraction Specimens. M. Grotenhuis, G. F. Durst, and A. G. Barkow. (Non-Destructive Testing, 1948, vol. 7, Summer Issue, pp. 15–18). A simple form of die and the preparation of powders for extruding through it to make X-ray diffraction specimens are described. Dies producing rods 0·040 and 0·25 in. in dia. are suitable for samples requiring firing. Samples not requiring firing are generally extruded to 0·010 in. in dia. Powders which pass through a 100–200 mesh screen are sufficiently fine, and gum tragacanth and gum ghatti are good binders. The method assures the rapid production of identical specimens.—R. A. R.

Methods of Testing Creep Resistant Alloys. W. F. Coxon. (Materials and Methods, 1948, vol. 28, Dec., pp. 76–78). Different methods of testing and specifying the creep of metals are explained with examples of the properties of different high-alloy chromium–nickel–molybdenum steels. The creep varies over different temperature ranges and one steel may have better creep properties at temperatures up to, say, 600° C. and poorer creep resistance at above 600° C. than another steel.—R. A. R.

Analysis of Some Characteristics of the Strength of Metals at High Temperature. I. A. Oding. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1365–1377). [In Russian]. High-temperature tests of metals can be divided into three main groups: (1) Those with results characterizing the degree of stability of the metal; (2) destructive tests, indicating the strength of the metals; and (3) tests of the resistance of the metal to deformation; as the last are considered the most important they are discussed in detail. The various types of deformation tests (based on relaxation, creep, or flow) are tabulated together with the conditions of temperature, initial stress and initial deformation pertaining to each, the respective differential equations also being shown. The methods are then critically considered and some limitations of this type of test are noted. Next, the mutual relationships between certain indices of the strengths of metals at high temperature are considered on the basis of two hypotheses: That which assigns the major rôle in the process of flow to the residual deformation, and that which stresses the importance of the time factor. These hypotheses are used in the schematic presentation of creep, flow, and relaxation phenomena, and conclusions are drawn regarding the range of applicability of each hypothesis and the conditions in which relaxation, creep and flow can be compared. These processes are then considered in detail, the interrelationships being presented graphically. The final case considered is that of creep under conditions of cyclic stresses and flow, the indirect calculation of the cumulative deformation being dealt with.—S. K.

Short-Time High Temperature Deformation Characteristics of Several Sheet Alloys. J. Miller and G. Guarnieri. (American

Society for Metals, Oct. 1948, Preprint No. 35). From short-time constant-rate tensile tests at elevated temperatures, true stress-strain characteristics have been determined for S.A.E. 1020 steel (used as a reference material) and four non-ferrous alloys. The data obtained were used to investigate the mechanics of deformation at elevated temperatures through the determination of the activation energies involved. The increase in such energy values with decrease in stress was attributed to the effect of elastic distortion on the crystal lattice. A simplified mechanism of deformation is described using these characteristics, and the relationship of the flow process to metallic diffusion is indicated.—J. C. R.

Stability of Steels at Elevated Temperatures. A. B. Wilder and J. O. Light. (American Society for Metals, Oct. 1948, Preprint No. 36). Results are given of examinations of twenty steels for evidence of structural changes, oxidation characteristics and impact properties after exposure for 10,000 hr. at 480°, 565° and 650° C. The influence of zirconium, niobium, and titanium on graphitization in molybdenum-bearing steels, without chromium, is discussed. The microstructure of 12% chromium ferritic stainless steels was unchanged and there was no oxidation. Tests with 17% and 27% chromium steels, chromium-nickel, and chromium–nickel–molybdenum steels are also reported.—J. C. R.

Trends in Use of Alloy Compositions for Heat Resistant Castings. E. A. Schoefer. (Industrial Heating, 1948, vol. 15, Oct., pp. 1720–1730, 1829–1831). The American production statistics for heat-resisting castings are analysed and the trends of production are studied. In 1939 two types of chromium–nickel steel (15/35 and 25/12) accounted for 68% of the total production; in 1948 the same alloys represented 77% of the total.—R. A. R.

The Creep and Cold Relaxation of Drawn Steel Wires. R. de Strycker. (Société Française de Métallurgie, Oct. 9, 1947: Revue de Métallurgie, Mémoires, 1948, vol. 45, Oct., pp. 411–414). The author discusses the creep and cold relaxation that occur in the patented and drawn hard steel rods used in reinforced-concrete construction. These rods are built into the structure under stress.—A. E. C.

Iron, Mild Steels, and Low Alloy Steels. R. B. Mears and S. C. Snyder. (Industrial and Engineering Chemistry, 1948, vol. 40, Oct., pp. 1798–1800). The properties of carbon steels, nickel and low chromium steels, and molybdenum steels which are of interest to chemical engineers are briefly reviewed, the data being taken from recent papers.—R. A. R.

High Silicon Cast Irons Resist High Temperatures. W. H. White and A. R. Alsea. (Foundry, 1948, vol. 76, Nov., pp. 68–69, 230). An investigation is reported on the properties of high-silicon (approx. 6%) cast irons at elevated temperatures. Results showed that at temperatures above 500° F. these irons had a greater impact resistance than ordinary grey cast iron. Growth tests over 41 cycles of heating to 1650° F., holding at this temperature for 4 hr. and air cooling to room temperature showed an 8% increase for ordinary irons, but the high-silicon irons showed practically no dimensional change. The test-bar scaled badly, but the scale was not adherent. An addition of 1·25% copper and 0·50% chromium to the high-silicon iron, however, made it extremely resistant to scaling. Data on growth are given and the resistance to growth of high-silicon cast irons is attributed to their high critical temperature.—J. C. R.

Effect of the Bainitic Structure on the Mechanical Properties of a Creep-Resisting Cr-Mo Heat-Treatable Steel. U. Wyss. (Von Roll Mitteilungen, 1948, vol. 7, Dec., pp. 51–70). New observations on the effect of the bainitic structure on the mechanical properties of a creep-resisting steel (C 0·15%, Cr 1·12%, Ni 0·80%, Mo 1·05%) at room temperature and on the creep at 500° C. are reported. The transformation of the austenite under isothermal and continuous conditions of cooling is discussed first. After the transformation in the bainitic stage some austenite particles remain in the structure and persist even at room temperature and at subzero temperatures. With slow cooling through the bainite stage this is specially noticeable, and the ferrite and austenite are coarser. On tempering the martensite and bainite at high temperatures, carbides are precipitated, especially in the 500–600° C. range, and this leads to secondary hardness. This reaction is facilitated when tempering pure martensite, and, if the temperature is high enough, the formation of the carbide corresponding to the phase equilibrium is completed quickly. When tempering the bainitic structure, however, equilibrium between the carbides and the ferritic matrix takes all the longer the stronger the liquation and the more marked the separation of austenite from ferrite in the previous decomposition of the austenite. Such structures also delay the formation of carbides at high tempering temperatures by their slow rate of transformation. This means that there is always a possibility of the precipitation of carbides after tempering and when this does occur it affects the mechanical properties at room temperature and the creep at high temperatures.—R. A. R.

A Metallurgical Investigation of Two Large Disks of CSA Alloy. E. E. Reynolds, J. W. Freeman and A. E. White. (National Advisory Committee for Aeronautics, 1948, Technical Note No. 1533: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8757). CSA alloy was thought to have promising properties for gas-turbine rotor service. The investigation was undertaken to ascertain the properties of this alloy in the form of large forgings. The two discs had the following composition: C 0·42%, Mn 4·47%, P 0·030%, S 0·016%, Si 0·41%, Cr 18·06%, Ni 5·2%, Mo 1·3%, W 1·2%, Nb 0·28%, balance iron. The two discs differed in that one was given an ageing treatment at 1400° F. for 24 hr. following solution treatment and prior to hot-cold-work. Data were presented in the form of tables and curves on the following properties; Tensile tests at room temperature and 1200° F; creep tests at 1200° F. under a stress of 25,000 lb./sq. in.; hardness tensile and rupture tests to show uniformity of the disc material; and stability studies based on hardness, tensile and magnetic tests and metallographic examination of the specimens after creep and rupture tests. It was concluded that the ageing treatment was beneficial to the rupture properties, whilst no effect in tensile, hardness or time-deformation properties was observed. Extrapolation of the rupture data indicated that the beneficial effects of the ageing would be lost at time periods of approximately 10,000 hr.

Contribution to the Study of Low-Alloy Steels Containing Titanium Additions for Forged Heat-Resisting Pieces. G. Delbart, R. Potaszkin and A. Kohn. (Société Française de Metallurgie, Oct. 9, 1947: Revue de Métallurgie, Mémoires, 1948, vol. 45, Oct., pp. 374–385). The influence of titanium on four low-alloy steels was investigated:

Steel	C, %	Si, %	Cr, %	Ti, %	Al, %	Mo, %
A	0·14	0·78	3·20	0·6	0·09	...
B	0·12	2·20	3·15	0·7	0·07	...
C	0·18	1·80	5·15	0·6	0·05	...
D	0·25	0·56	1·60	0·3	0·07	0·42

The manganese content was about 0·45%, and steels *B* and *C* contained about 0·15% of nickel. The titanium occurred in the microstructure in the form of numerous inclusions, some coarse and of characteristic appearance and colour, others extremely fine. It was present in two forms, insoluble or soluble in sulphuric acid according to whether the titanium content was not more than four times the carbon content or exceeded that figure. Various heat-treatments had much influence on the creep resistance of these steels, even when they were without effect on the mechanical properties in the cold state. Raising the quenching temperature increased the creep resistance; there seemed to be an optimum tempering temperature which varied with the composition and the quenching conditions. The mechanical properties varied largely with the structural conditions of the steels. The toughness was considerably reduced by holding at temperatures near 550–650° C. or by cooling slowly after tempering; this brittleness seemed to arise from the displacement of the transition zone in the toughness/temperature curve to temperatures above room temperature. Silicon causes a similar displacement of the transition range, and high-silicon steels have a negligible toughness at room temperature, whatever the previous heat-treatment. Steel *A* after oil-quenching from 1050° C. and tempering at 650° C. gave a creep resistance of 14 kg./sq. mm. at 560° C. and satisfactory mechanical properties in the cold. Steel *B* also offered a good resistance to creep—at times it showed negative creep corresponding to structural modifications in the steel taking place during the test. The creep resistance of the other steels were lower; the titanium content of steel *D* was lower than the others and the titanium/carbon/ratio did not exceed 1·2. All four steels forged well. A. E. C.

The Effect of Titanium on Nitrogen in Steel. G. F. Comstock. (Metal Progress, 1948, vol. 54, Sept., pp. 319–322). Experiments relating to the effect of the titanium/carbon ratio

on the nitrogen content of steel are reported. Titanium additions greatly reduce the amount of nitrogen in the soluble state, in fact, they stabilize the nitrogen in an insoluble form even when there is not enough present to stabilize all the carbon. The soluble nitrogen is just as low when the titanium/carbon ratio is between 1·6 and 3·6 as it is when this ratio exceeds 4. In a thoroughly killed steel titanium is not uniformly distributed when the nitrogen is high; titanium and nitrogen both segregate to the top of the ingot whereas carbon and columbium do not. Titanium carbide does not segregate from steel at temperatures above the melting point to as great an extent as titanium nitride.—R. A. R.

Steel and Aluminium for Automotive Products Compared. D. F. Toot. (Society of Automotive Engineers: Materials and Methods, 1948, vol. 28, Oct., pp. 69–73). The properties of steel and of aluminium and aluminium alloys are compared from the point of view of their use in automobile and motor lorry construction. The endurance limit of unheat-treated wrought aluminium is somewhat less than 50–75% of that of hot-rolled 0·10% carbon steel and in the cold-worked state the ratio would remain about the same. Sand-cast and permanent-mould cast aluminiums have endurance limits less than half that of cast iron, but die-cast aluminium has an endurance limit equal to or slightly better than 'automotive' cast iron; die-cast aluminium is, however, notch sensitive. Aluminium for exterior body panels does not seem feasible. Steel, cast iron, and aluminium will continue to be used in automobile construction, and the proportion of aluminium to the total weight is likely to increase.—R. A. R.

Nickel Alloy Steels for Machine Tools. (Mond Nickel Co., Ltd., 1948, Pamphlet). The effects of nickel additions to steel are described, tables are included showing the limits of thickness or section of hardened and tempered En nickel alloy steels to produce tensile strengths of 40 to 100 tons/sq. in., and their compositions and applications, and thirteen tempering diagrams for a number of these steels are presented. R. A. R.

Standardization of Metallic Materials in Norway. (Teknisk Ukeblad, 1948, vol. 95, Sept. 30, pp. 487–492). [In Norwegian]. The article was written in connection with a meeting held on September 10, 1948, for the purpose of investigating the possibilities of a resumption of the work of standardization of iron and steel in Norway. A survey is made of the work already performed in the establishment of Norwegian standards within the range in question, and elucidates the present situation. The question was raised if the work of standardization, successfully executed during the last few years in Sweden might constitute the basis for the compilation of Norwegian standards. A summary of the Swedish work on standardization is given.—J. K.

Standardization of Tool Steels in Sweden. R. Apri. (Verkstäderna, 1948, vol. 44, No. 8, pp. 166–168). [In Swedish]. The author states his opinion on standardization in general and then outlines the ways in which the work of standardization has developed. The eighteen tool steels, now standardized in Sweden, are shown in a table, and reasons are given for this selection. The specifications are not to be considered as irrevocably settled but ought to be adjusted according to the development within the range in question.—J. K.

New Developments in Tool Steels. Part II. G. A. Roberts. (Tool and Die Journal, 1948, vol. 14, Aug., pp. 48–50: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 52). This part deals with molybdenum irons, chromium–tungsten steel, vanadium in chromium hot-work steels, and high-speed steels. A table gives compositions of some high-speed steels.

Free Cutting Steels. T. C. Du Mond. (Materials and Methods, 1948, vol. 28, Oct., pp. 95–102). The characteristics and properties of free-cutting steels are described and discussed and lists are given of the composition of the American Iron and Steel Institute free-cutting steels with their equivalent S.A.E. numbers; machinability ratings are given and are related to that of steel B1112 which is a Bessemer steel with 0·13% max. of carbon. They are unsuitable for welding. Recommendations are made on heat-treatment and cutting fluids.—R. A. R.

Large Crystal Grain Size in Silicon–Chromium Valve Steel. C. C. Hodgson and H. G. Brown. (Journal of The Iron and Steel Institute, 1949, vol. 161, Feb., pp. 81–85). Attention is drawn to a coarsely crystalline condition which has been observed in valves and valve forgings made of silicon–chromium steel. The relevant specifications are examined and their requirements considered. It is shown that certain British specifications do not exclude the production of coarsely crystalline valves. The influence of heat-treatment on microstructure is examined and experiments on plastic deformation are described; it is held that these establish that plastic deformation at a red heat can cause a condition of critical strain capable of leading to critical grain growth on recrystallization. It is shown that a satisfactory structure can result from widely differing mechanical operations and heat-treatments, but certain combinations of these must be avoided if the absence of critical grain growth is to be assured.

The Pseudoflakes in High-Speed Steel—Their Origin and Their Effect on the Hardness of the Tempered Steel. E. Orosco. (Boletim da Associação Brasileira de Metais, 1948, vol. 4, pp. 300–332: Chemical Abstracts, 1948, vol. 42, Nov. 10, cols. 8134–8135). Samples of eight factory-made high-speed steels with C 0·70–0·80%, Si 0·15–0·25%, Mn 0·25–0·35%, Cr 4·00–4·50%, W 18·00–20·00% V 0·20–0·30%, P not more than 0·025%, and S not more than 0·020%, were examined macro- and microscopically and tested for hardness before and after tempering. A content of up to 0·5% of tin did not contribute to the appearance of pseudoflakes, but contributed to the lowering of the hardness of the tempered high-speed steel. The fracture of the high-speed steel changed with the increase of the tempering temperature from normal to marmorized to pseudoflakes. Abnormal fractures with pseudoflakes showed a lowered tempering hardness while the Rockwell value remained the same. The pseudoflakes were a product of the growth of the austenite grains; if this growth was less favoured, marmorized fractures appeared. The development of the bigger austenite grain was inhibited by a uniform, intra- and inter-crystalline distribution of iron and tungsten carbides in small globules. The coalescence of these globules led to their accumulation in the interior of the austenite grain and allowed neighbouring austenite grains an intimate contact and an easier growth. This process can be provoked by repeated heating and tempering. Also warm plastic deformation (forging) favoured the appearance of the pseudoflakes for the same reason. A reheating to low temperatures (900°) could avoid the fracture with pseudoflakes to a certain degree, while high tempering temperatures (1250°) favoured the marmorized fracture and pseudoflakes. It is recommended to perform the casting at as low a temperature (initial temperature 1550°) and as quickly as possible, and not to use scheelite for tungsten additions.

Stainless Steels, Constitution, Properties and Heat Treatment. V. Chiaverini. (Geologia e Metalurgia, Universidade de São Paulo, Escola Politécnica, 1948, Boletim No. 5, pp. 13–79: Chemical Abstracts, 1948, vol. 42, Nov.10, col. 8135). This is a review with twenty-seven diagrams and illustrations.

Investigations on Special Steels in French Metallurgical Laboratories. A. Michel. (Metalen, 1948, vol. 3, Oct., pp. 31–35; Nov, pp. 63–65; Dec., pp. 88–91). [In Dutch].

Spring Design and Manufacture. J. A. Roberts. (Wire and Wire Products, 1948, vol. 23, June, pp. 479–483; July, pp. 583–588, 624–626). *See* Journ. I. and S.I., 1948, vol. 159, June, p. 231.

Alloy Cast Irons. A. B. Everest. (British Engineering Export Journal, 1948, vol. 31, Dec., pp. 970–977). Recent foundry progress in Great Britain in the manufacture of alloy cast irons is reviewed with illustrated descriptions of many applications.—R. A. R.

METALLOGRAPHY

Film-Adaptor for Microscopes. A. A. Dyatlov and A. I. Verkhoshapov. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1397–1399). [In Russian]. Details are given of a simple device which facilitates the use of biological microscopes for purposes of metallographic photography; a photomicrograph of a cast-iron obtained with this device is shown.—S. K.

The Phase-Contrast Incident-Light Microscope. F. W. Cuckow. (Journal of The Iron and Steel Institute, 1949, vol. 161, Jan., pp. 1–10). A review is given of experiments in the comparative microscopy of metals leading to the conclusion that new information can be gained from a knowledge of the various levels existing in the surface of the prepared metallurgical specimen. The means already available for the assessment of these levels are discussed. A new instrument

for this work, a phase-contrast incident-light microscope, is described. A comparative microscope is also described in which a single field of view is divided into two parts, one of which is seen under phase-contrast conditions and the other under normal microscopical conditions. The dividing line can be moved across the field of view. Photomicrographs from the instrument are shown. These indicate that the instrument is a useful addition to the tools available to the metallurgist.

The Surface Appearance of Polished Metals—Physical and Psychological Considerations. G. E. Gardam and J. F. Mills. (Journal of the Electrodepositors' Technical Society, 1948, vol. 24, pp. 17–26 : Electroplating, 1948, vol. 1, Dec., pp. 774–777).

Stainless Steel through the Microscope. T. A. Pruger. (Steel Horizons, 1948, vol. 10, No. 4, pp. 14–15 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8752). This is a brief discussion of the use of the microscope and the X-ray spectrograph in the study of alloys, accompanied by constitutional diagrams of typical stainless steels.

Electropolishing Metal Specimens. J. Piaskowski. (Hutnik, 1948, vol. 15, No. 2, pp. 54–60). [In Polish]. Electropolishing apparatus and techniques for iron and steel, copper, aluminium, magnesium, tin, lead, and other metals, and their alloys are described.—W. J. W.

Automatic Polishing of Metallographic Samples. E. D. Holt. (Metal Progress, 1948, vol. 54, Sept., pp. 350–352). Modifications and improvements to T. C. Jarrett's method of polishing specimens are described (*see* Journ. I. and S.I., 1938, No. II, p. 395A). The polishing machine has a horizontal lap rotating in one direction at 96 r.p.m. while the specimen holder, which carries 12 specimens, is driven in the opposite direction at 90–92 r.p.m. A 900-grit abrasive is used first on an alundum stone lap and then on a lead lap, and finally on a Vel-Chamee cloth lap.—R. A. R.

Metallography of Electro-Deposited Surfaces. A. T. Steer. (Electroplating, 1947, vol. 1, Nov., pp. 5–15, 28 ; Dec., pp. 49–53 ; 1948, Feb., pp. 153–165). The preparation and examination of microspecimens of electroplated surfaces are discussed in detail in Part I, and in Part II the author traces, with the aid of numerous photomicrographs, the progress of a metal surface through the process of machining, emery-bobbing, and buffing, showing the changes in the character of the surface, the result of feeding too rapidly in machining, and of forward and backward movements in polishing.

X-Ray Camera for the Precision Measurement of Crystals. M. M. Umanskii, S. S. Kvitka and Iu. A. Bagaryatskii. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1343–1350). [In Russian]. Techniques used in connection with the production of rotation and oscillation photographs of monocrystals are described and an account is given of an X-ray camera of improved design for use in precision measurements by these methods.—S. K.

Theory and Computation of Grain Structure in Solidifying Metals. H. Fromm. (Optik, 1948, vol. 3, pp. 137–164 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8742). The formation and subsequent growth of nuclei on solidification of molten metals and the resulting grain structures are considered under different conditions : at constant temperature, under uniform withdrawal of heat, and for constant grain growth. With the data available in the literature for solid and liquid iron (density, specific heat, heat of fusion) the distribution and the size of the resulting grains are computed.

The Theory of Recrystallization. K. Lücke and G. Masing. (Zeitschrift für Metallkunde, 1948, vol. 39, Oct., pp. 291–293). In an earlier paper (*see* Journ. I. and S.I., 1948, vol. 159, May, p. 102) C. Petersen has represented a nucleus as an isotropic compressed sphere and has calculated that, as it grows at the expense of the surrounding matter which is stressed by the pressure, the elastic energy of the system is very rapidly dissipated and that it remains capable of growth because of its compression energy. The present authors present a simpler form of calculation, and point out that, as the growth ceases when the radius of the nucleus attains five times its initial length, Petersen's theory does not affect the subsequent recrystallization mechanism.—R. A. R.

The Refined Graphite Eutectic with Round, Spheroidal Graphite. C. F. Adey. (Neue Giesserei, 1948, vol. 33/35, Sept., pp. 67–74). The author critically reviews recent literature on the forms of graphitic carbon in cast iron and methods of influencing them. He believes it is possible to refine the graphite eutectic, but not *via* the lamellar arrangement which E. Scheil regards as normal, but the present author regards as an abnormal eutectic crystallization falling into the third category of Scheil's grouping. The primarily precipitated graphite, present in small amounts, constitutes the second category, and it is through this that the first type of crystallization, namely solid solution formation, commences. The fact that spherolitic carbon can be obtained by undercooling also supports the concept of an abnormal eutectic crystallization. Although there is initially a high rate of diffusion of the carbon there is nevertheless some linkage in the crystallization as the neighbourhood of the spheroids is deprived of carbon and the melt crystallizes on the graphite spheroids in the same manner as has been established for flakey graphite.

Many stages of carbon precipitation are illustrated by twenty-one micrographs.—R. A. R.

Separation of Carbides during Tempering of Quenched Alloy Steel. V. I. Arkharov and S. T. Kiselev. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 59, pp. 1571–1574 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8749). Electrolytic extractions were made on twelve steels containing C 0·56–1·17%, Cr 1·06–4·14%, Ni 0·31–2·02%, Mo 0–0·5%, W 0–2·5%, Mn 0·16–1·36%, Si 0·23–0·45%, P 0·015–0·028% and S 0·009–0·015% in the following states : (1) Annealed, and (2) quenched and tempered 8 hr. at (*a*) 400°, (*b*) 500°, and (*c*) 600°. The residue obtained was subjected to chemical analysis and X-ray examination. Stable carbides were found in (1) and (2*c*) while a "low-temperature phase" predominated in (2*a*) and (2*b*). In addition to iron, the low-temperature phase contained the alloying elements (chromium, tungsten, molybdenum) but to a lesser extent than the stable carbides. The chromium, tungsten, and molybdenum contents increased with an increase in the corresponding alloy content of the steel and with an increase in the tempering temperatures. The stability of the low-temperature phase decreased as its alloy content increased. The crystal structure could not be determined because of the numerous lines and weak diffraction pattern.

New Contributions to the Knowledge of the Carbides in Alloy Steels. W. Koch and H-J. Wiester. (Stahl und Eisen, 1949, vol. 69, Feb. 3, pp. 73–79). Tests in which the carbides in steels with up to 6% of molybdenum were isolated showed the powerful effect of carbon in that the amount of alloying elements in the carbides in low carbon steels is very much higher than when the steels are high in carbon. The factor controlling the alloying elements in the carbides is not the alloying elements in the steel, but that in the solid solution which is in equilibrium with the carbide. It is surprising that in steels with 1·0–1·1% of carbon the molybdenum in the carbide does not increase (by weight) any more rapidly than manganese in the corresponding manganese steels ; however, with this carbon content, the cubic crystalline carbide $Fe_{21}Mo_2C_6$ occurs at 0·94% molybdenum after transformation to the pearlitic stage ; this complex carbide has a crystalline structure corresponding to the carbide $Cr_{23}C_6$ in chromium steels. The same carbide was found in a steel of the same series with 3·18% of molybdenum as well as in a 0·17% carbon steel with 0·46% of molybdenum after transformation to pearlite. The carbide Fe_3Mo_3C was determined by X-ray methods in 0·1% carbon steels with 6·3% and 12·5% of molybdenum after annealing at 700° C. When steels with up to 3·18% of molybdenum were transformed in the intermediate stage, or when the martensite was tempered in this temperature range, a fairly strong molybdenum-bearing iron carbide was formed.

The iron-molybdenum compound precipitated from almost carbon-free alloys with 6·3% and 12·5% of molybdenum had a composition agreeing satisfactorily with the formula Fe_2Mo_2 after taking some solubility for iron into account.

In nickel and silicon steels the carbide has a lower alloying-element content than that corresponding to the average amount in the steel. Under equilibrium conditions, the formation of carbides from these non-carbide-forming elements presupposes a migration of the atoms of the alloying elements out of the lattice spaces in which the carbides will be formed. According to A. Hultgren's work, this migration does not occur with intermediate-stage transformations.

The composition of the carbides in chromium steels, whether brittle or tough after tempering, did not differ. A high phosphorus content in the residue after isolation of the carbides provides no explanation for temper brittleness without knowing in what form it is present and where it comes from.—R. A. R.

Delta Ferrite Formation and Its Influence on the Formation of Sigma in a Wrought Heat Resisting Steel. J. J. Gilman, P. K. Koh, and O. Zmeskal. (American Society for Metals, Oct. 1948, Preprint No. 28). For this investigation the steel used was 19–9DL supplied as bar stock, stress-relieved at 650° C. (C 0·27%, Cr 18·82%, Ni 9·59%, Mo 1·34%, W 1·39%, Nb 0·54%, Ti 0·32%, Mn 1·20%, Si 0·66%, S 0·01%, P 0·02%). Two series of specimens were used; the first determined the effect of solution treatment temperature (980° to 1315° C.) on the amount of delta ferrite formed in 1 hr., the second determined the effect of increasing time (2 to 256 min.) on the amount of delta ferrite formed at one temperature (1290° C.). The formation of high temperature ferrite was studied metallographically. The structural stability at 650 to 870° C. was studied for the case of an initial structure high in ferrite (22–23%) and of an initial structure low in ferrite (2–3%). The sigma phase was investigated and it was found that sigma formed from austenite as well as ferrite; the presence of ferrite in the initial structure hastened the formation of sigma, and cold work accelerated the formation of sigma to a greater extent than the presence of ferrite in the initial structure did.—J. C. R.

The Allotropy of Iron and that of Helium. C. Benedicks. (Société Française de Métallurgie, Oct. 10, 1947: Revue de Métallurgie, Mémoires, 1948, vol. 45, Oct., pp. 397–401). The author discusses the five different ways in which allotropic changes can proceed, and suggests that Osmond's β-iron is an α-iron containing " in solution " a certain quantity of atoms characteristic of γ-iron, which exists in the temperature range between A_2 and A_3. On cooling γ-iron below A_3 the carbon dissolved in it becomes supersaturated and is precipitated, with an evolution of heat, at a certain temperature (near A_3.) Further, the ferromagnetism of pure α-iron diminishes on heating and disappears at a certain Curie point (near A_2), giving rise to a thermal change (heat evolution on cooling). These two points are considered sufficient to explain the two feeble critical points near A_2 found by Osmond. The allotropy of helium is also discussed.—A. E. C.

Graphical Classification of Multiple-Component Alloys. L. V. Al'tshuler. (Bulletin de l'Académie des Sciences, U.R.S.S., Classe des Sciences Techniques, 1946, pp. 603–610; Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8757). The author discusses various methods of plotting systems containing four to seven components, with particular reference to high-alloy steels.

Investigation of the System Mo^{+6}/Mo^{+5}. V. S. Syrokomskii and V. B. Avilov. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1279–1288). [In Russian]. An account is given of an experimental investigation of the oxidation-reduction potential of the system Mo^{+6}/Mo^{+5} in relation to the concentration of mineral acid, with varying concentrations of oxalic, tartaric or phosphoric acids. The system Fe^{+3}/Fe^{+2} was similarly investigated and the mutual effects of the two systems are discussed.—S. K.

Binary and Ternary Interstitial Alloys. I—The Iron–Nitrogen System: The Structures of Fe_4N and Fe_2N. K. H. Jack. (Proceedings of the Royal Society, Series A, 1948, vol. 195, Nov. 12, pp. 34–40). The ζ-iron nitride phase (Fe_2N), the existence of which is confirmed, is prepared by passing ammonia over iron at temperatures not exceeding 450° C. and under such conditions that the partial pressure of hydrogen is negligible. The positions of the nitrogen atoms in $\gamma'(Fe_4N)$ and in ζ are determined.

γ' is a 'normal' 12a6 interstitial structure, the cubic unit cell of which contains four iron atoms at 0 0 0, $\frac{1}{2}\frac{1}{2}$ 0, $\frac{1}{2}$ C $\frac{1}{2}$, 0 $\frac{1}{2}\frac{1}{2}$, and one nitrogen atom at $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; at 6·1 weight% N, a = 3·787kX.

ζ has a distorted 12b6 structure. The unit cell, with dimensions a, 5·512; b, 4·820; c 4·416 kX. at 11·3 weight % N, contains eight iron atoms at 0 0 0, $\frac{1}{2}$ 0 0, $\frac{1}{4}\frac{1}{2}$ 0, $\frac{3}{4}\frac{1}{2}$ 0, 0 $\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}\frac{1}{2}\frac{1}{2}$, $\frac{1}{4}\frac{5}{6}\frac{1}{2}$, $\frac{3}{4}\frac{5}{6}\frac{1}{2}$, and four nitrogen atoms at $\frac{1}{4}\frac{1}{6}\frac{1}{4}$, $\frac{1}{2}\frac{3}{4}\frac{1}{4}$, $\frac{3}{4}\frac{1}{6}\frac{3}{4}$, 0 $\frac{3}{4}\frac{3}{4}$.

Both γ' and ζ are fully ordered interstitial alloys.

Binary and Ternary Interstitial Alloys. II—The Iron–Carbon–Nitrogen System. K. H. Jack. (Proceedings of the Royal Society, Series A, 1948, vol. 195, Nov. 12, pp. 41–55). Chemical and X-ray investigation of the reaction of carbon monoxide with iron nitrides and of the reaction of ammonia with iron carbides discloses the existence of iron carbonitrides—a series of new ternary interstitial alloys containing iron, carbon and nitrogen. ζ-phase carbonitrides, with structure similar to those of ζ-iron nitrides, have a range of homogeneity extending approximately from Fe_8N_4 to Fe_8C_3N. The latter is isomorphous with Fe_2N. ϵ-phase carbonitrides, which are isomorphous with ϵ-iron nitrides, have a composition range of approximately 25 to 33 atomic % nitrogen plus carbon, *i.e.*, from Fe_3X, to Fe_2X, in which the higher carbon concentration limit is not less than 16 atomic %.

Probable phase fields for part of the iron–carbon–nitrogen system are given on a ternary diagram.

Prolonged reaction of carbon monoxide with iron nitrides results in complete elimination of nitrogen. Below 500° C. the product is a carbide of iron, now called iron percarbide, the narrow composition range of which includes $Fe_{20}C_9$. Above 500° C. the product of the same reaction is cementite.

Binary and Ternary Interstitial Alloys. III—The Iron–Carbon System: The Characterization of a New Iron Carbide. K. H. Jack. (Proceedings of the Royal Society, Series A, 1948, vol. 195, Nov. 12, pp. 56–61). Cementite and iron percarbide are conveniently prepared by the methods described in the previous paper (*see* preceding abstract).

Iron percarbide has a narrow range of composition near 31 atomic % carbon and is identical with a carbide, assumed to be Fe_2C, which was previously obtained by Hägg (1934). The iron percarbide unit cell is probably either orthorhombic, with dimensions

a, 9·04(3); $b = \sqrt{3}.a$, 15·66(3); c, 7·92(1)kX.,

or hexagonal, with dimensions

$a^1 = 2a$, 18·08(6); $c^1 = c$, 7·92(1)kX.

These two possible units of structure are simply related, the volume of the latter being twice that of the former. The orthorhombic unit cell contains approximately 80 iron atoms, and the empirical formula for the carbide is $Fe_{20}C_9$. Although the existence of a carbide Fe_2C is not disproved, it is unlikely that it has been prepared in this or any previous work.

The cementite is identical with specimens formed below 700° C. in steel and obtained by the action of carbon monoxide on ferric oxide.

Both carbides are metastable. Iron percarbide decomposes giving cementite and carbon, and cementite breaks down less rapidly to give α-iron and carbon.

CORROSION

Application of a Colorimetric Method to the Study of the Speed of Corrosion of Ferrous Alloys. L. Cavallaro and A. Tani. (Atti dell'Accademia Scientifica Ferrara, 1946–1947, vol. 24, No. 2, pp. 225–234: [Abstract] Centre de Documentation Sidérurgique, Bulletin Analytique, 1948, vol. 5, July, p. 39). This is a study of the colorimetric analysis of the products of corrosion and the influence of pH on the corrosion of mild steel. Applications of this investigation in the study of galvanic corrosion and corrosion in the presence of inhibitors, are considered.

The Atmospheric Corrosion of Metals. G. Schikorr. (Archiv für Metallkunde, 1949, vol. 2, No. 7, pp. 223–230). A general picture of the atmospheric corrosion of metals is given by reviewing the literature, and some recent investigations at Berlin-Dahlem are quoted which showed that the corrosion of metals in the winter months varies directly with the concentrations of sulphur compounds in the atmosphere. In the first month of exposure lead, zinc, brass, copper, and nickel corroded at practically equal rates and iron at about twice this rate.—R. A. R.

The Corrosion of Heating Surfaces in Boiler Plates: Further Studies in Deposit Formation. J. R. Rylands and J. R. Jenkinson. (Journal of the Institution of Electrical Engineers, 1948, vol. 95, Part II, Dec., pp. 668–669). *See* Journ. I. and S.I., 1948, vol. 159, May, p. 108.

Stabilization of Austenitic Stainless Steel. S. J. Rosenberg and J. H. Darr. (American Society for Metals, Oct., 1948, Preprint No. 27). A study was made of the resistance to intergranular attack of twenty-three 18/8 austenitic corrosion-resisting steels in twelve different initial conditions. Susceptibility to intergranular attack was determined after seven sensitizing treatments, followed by exposure for a maximum

of 14 days in a boiling acidified copper sulphate solution. It was found that maximum susceptibility to intergranular attack was developed by sensitizing either 8 or 21 days at 550° C. Straight carbon austenitic corrosion-resisting steels were vulnerable to intergranular embrittlement, although susceptibility decreased as the carbon content decreased. Niobium- and titanium-treated steels were satisfactorily resistant provided the niobium/carbon and titanium/carbon ratios were sufficiently high. Stabilizing heat-treatment at 870° C. markedly improved the performance of titanium-treated steels having a high titanium/carbon ratio but did not materially affect niobium-treated steels. Steels having similar ratios of stabilizing element to carbon had approximately the same degree of susceptibility to intergrannular attack regardless of the carbon content.—J. C. R.

The Catalytic Oxidation of Sulphur Dioxide on Metal Surfaces. Part I. G. Tolley. (Journal of the Society of Chemical Industry, 1948, vol. 67, Oct., pp. 369–373). The rate of catalytic oxidation of sulphur dioxide on the surface of mild steel, and aluminium-sprayed and aluminized steels is reported. The effect of variation in temperature, gas velocity and concentration of sulphur dioxide has been measured. The presence of water vapour has been shown to inhibit catalytic oxidation on the surfaces tested. The catalytic activity of mild steel increases considerably upon exposure ; aluminium-sprayed specimens exhibit a maximum in catalytic activity after 7–12 hr. exposure with a decrease upon further exposure ; aluminized specimens show constant catalytic activity. Coating steel with aluminium considerably reduces the rate of catalytic oxidation of sulphur dioxide.

The Catalytic Oxidation of Sulphur Dioxide on Metal Surfaces. Part II—The Reaction of Sulphur Dioxide and Oxygen at a Mild Steel Surface. G. Tolley. (Journal of the Society of Chemical Industry, 1948, vol. 67, Nov., pp. 401–404) The rates of combination of sulphur dioxide and oxygen at a mild steel surface at various temperatures with dry and moist gases have been measured. Sulphide and sulphate formation is found to occur simultaneously, the sulphide being concentrated near to the surface of the basis steel. The rate of sulphate formation is greatest between 580° and 635° corresponding to the maximum catalytic activity of Fe_2O_3. Water vapour inhibits sulphide and sulphate formation, but increases the rate of oxidation.

The Corrosion of Metals in Atmospheres Containing Sulphur Dioxide. Part I. G. Tolley. (Journal of the Society of Chemical Industry, 1948, vol. 67, Nov., pp. 404–407). Results are presented for the corrosion of mild steel, and aluminium sprayed and alumininized steel by air containing from 0·2%–6% SO_2 at temperatures of 300°–700°. The influence of gas velocity, temperature, and concentration of SO_2 has been found. Corrosion time curves for up to 40 hours' exposure are given for 0·2% and 4% SO_2-air mixtures at 600°. Small concentrations of water vapour in the gas decrease corrosion of mild steel, but further additions increase corrosion. The results show that the catalytic formation of sulphur trioxide on the surface of the metals is of great importance in determining the rate of corrosion.

A Study of the Corrosion Resistance of High-Alloy Steels to an Industrial Atmosphere. H. T. Shirley and J. E. Truman. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 367–375). The tests described were designed to study the effects of composition and surface finish on the behaviour of higher alloy steels when exposed for prolonged periods to severe industrial atmospheric conditions, without attention to the cleansing treatment normally recommended for such materials. The intention was twofold ; the results were to provide information as to the most suitable compositions for use where regular cleansing would be impracticable, and also to serve in comparing, directly, the behaviour of these higher alloy steels with that of lower alloy steels exposed under similar conditions.

The series included some 450 samples, covering 22 steels and 5 non-ferrous materials, all in sheet form. The three types of surface finish tested were pickled, emeried, and mirror-polished. Exposure was for two and five years with vertical specimens, and for five years with specimens exposed at 12° to the horizontal.

In respect of composition, the behaviour of 18/8/2½ chromium–nickel–molybdenum and 24/12/3 chromium–nickel–tungsten steels was outstandingly good, with losses of the order of only one-thousandth that of mild steel. In general the more resistant steels tended to show higher losses in the case of the emeried samples, than for the other two surface finishes, the effect being small for the vertical exposure stands, but more considerable in the case of the horizontal stands. Although comparison with earlier tests for one month indicated a general tendency for higher rates of loss in the initial stages of exposure, there was no indication of any notable change in rate of attack with time over the two-year to five-year periods. The losses were considerably higher than various reported figures from American tests (reflecting the greater severity of the test conditions), and were much less favourable to plain 18/8 chromium–nickel steel than reports, based on exposure, by some other investigators.

The results for the non-ferrous materials were in line with those expected from previously published figures, and show all five materials to give higher losses than most of the special steels. Although, in some cases, this may be offset to some extent by a pitting tendency in the case of the steels, the outstanding superiority of the 18/8/2½ chromium–nickel–molybdenum and 24/12/3 chromium–nickel–tungsten steels is clearly demonstrated, with losses of the order of only a hundredth of those of the non-ferrous materials.

Effect of Oxygen Adsorbed on Iron on the Contact Potential Difference. R. Kh. Burshtein and M. D. Surova. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 61, pp. 75–78 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8585).

Passivation of Iron by Gaseous Oxygen. N. A. Shumilova and R. Kh. Burshtein. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 61, pp. 475–478 : Chemical Abstracts, 1948, vol. 42, Nov. 20, cols. 8585–8586).

Corrosion of a Steel Ship in Sea Water. K. N. Barnard. (Canadian Journal of Research, 1948, vol. 26, Sept., pp. 374–417). The corrosion of a steel ship in sea water was investigated by measuring the differences in potential in the sea close to the ship. It was found that : (1) The corrosion history of a ship may be followed in reasonable detail by this method. (2) The chief cathodic sinks occur at (*a*) painted steel areas, (*b*) bronze propellers, and (*c*) the water line. (3) Cathodic protection of a ship appears to be practicable ; a rather low current requirement is indicated (less than 30 amp. or 6 milliamp./sq. ft. for the minesweeper tested). (4) The current from an active anode spreads over a considerable area. (6) Zinc is not satisfactory as a sacrificial anode for cathodic protection in sea water. Some failures of the present anti-corrosion measures are indicated, and some remedies are suggested. R. A. R.

Cathodic Protection of Steel Water Tanks. P. E. Pallo. (Journal of the American Water Works Association, 1948, vol. 40, July, pp. 701–711). An investigation is described in which four tanks were made out of four 18-in. lengths of 10-in. steel pipe ; these were sand-blasted clean both inside and out ; the outside was painted and the inside left bare ; they were filled with water and emptied and refilled daily for 5½ months. One tank was provided with an aluminium anode with an applied external potential, the second with a galvanic magnesium anode, the third with electrical resistances attached to the outside through which a direct current was applied. The fourth tank, used as a control, had no protection. A properly installed sacrificial aluminium anode provided with an external potential was found to prevent adequately the corrosion of bare steel. A sacrificial galvanic magnesium anode inhibited the corrosion of the bare steel surface after an initial aggressive attack. The electrodeless circuit gave no protection. The concentration of dissolved oxygen in the stored water did not increase when aluminium or magnesium anodes with an applied potential were used. R. A. R.

The Local-Cell Effect when Iron Dissolves in Hydrochloric Acid. K. Wickert and H. Pilz. (Archiv für Metallkunde, 1948, vol. 2, No. 6, pp. 207–216). In an earlier paper F. Tödt has stated that surface preparation with emery and by grinding has little effect on the solubility of iron in hydrochloric acid. The present authors dispute this and carried out extensive experiments with almost pure soft iron. In a range of roughness from cleaning with a rough file to polishing with 0000 emery the rate of solution decreased with increasing smoothness. The smoother specimens have a smaller number of active localities than the filed specimens. The high initial rate of solution of a clean metal surface (*i.e.*, with no visible

oxide coating) is governed by the degree of activity and number of active localities, not by the invisible oxide coating. R. A. R.

Control of Metal Corrosion. W. T. McClenahan. (Journal of the American Water Works Association, 1948, vol. 40, June, pp. 606–614). The paper describes briefly the occurrence and probable causes of the corrosion of metals at a sewage works in the Chicago district, and the steps taken to inhibit corrosion. For outside exposure where conditions are not too damp, a linseed oil paint reinforced with phenolic varnish is applied. To protect steel to be used under water, it is first thoroughly cleaned by brushing and scraping, then treated with phosphoric acid, then given a priming coat of phenolic paint containing about 25% by weight of zinc chromate, finally, a heavy film of bitumen is applied. The cathodic protection, using magnesium anodes, of a very large steel tank holding effluent from a chlorinated aeration plant is also described.—R. A. R.

Underground Leaks *versus* Cathodic Protection. A. Smith, jun. (Chemical Engineering, 1948, vol. 55, Nov., pp. 139–141). An account is given of the aggregate of the results obtained by installing cathodic protection to certain buried pipelines at the plant of the Dow Chemical Co., Midland, Mich. By December, 1947, 619 anodes (10,000 lb. of magnesium) had been installed in three years and the leak rate had been reduced from 145 in 1943 to 45 in 1946, and 54 in 1947. The cost was about $12,400 which saved about $6,500 per annum in repairs alone.—R. A. R.

Corrosion and Anodic Behaviour of Iron and Steel in Dilute Acids. J. Calleja. (Anales de la Real Sociedad Española de Física y Química, 1948, vol. 44, Series B, pp. 553–570: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8767). Variation of pH in the electrolyte in direct contact with the anode was determined as well as the relations between these values and other variables in the electrolytic process. The anodes used were steel, particularly "ferrotype" and mild steel. The electrolyte was 0·1–0·05 N H_2SO_4. Curves pH $v.$ time are parabolic. Some of them show two cessations of increase in pH at 1·85 and 2·25, perhaps due to the formation of H_2SO_4–$Fe(HSO_4)_2$ and $FeSO_4$–$Fe(HSO_4)_2$ systems, perhaps due to the system xH_2SO_4, $yFe(OH)_2$ for which definite values of x/y act as a buffer at these pH values. In the anodic solution about a horizontal piece of iron there is an ohmic resistance due to drop of conductivity in the layer of electrolyte close to the anode, so that current density falls and anodic potential becomes more negative; conditions thus become unsuitable for the passive state. The passive state appears only at current densities corresponding to passive potentials. In the present case, passivity cannot be a time phenomenon or a result of increase in pH, because the latter never exceeds five.

Corrosion Resistance Tests of Materials Subjected to Sodium Chlorite Liquors Used by the Textile Industry. J. Meybeck, N. Iwanow, and A. Loebenstein. (Bull. Inst. Textile France, 1948, Mar., pp. 39–60: [Abstract] Chimie et Industrie, 1948, vol. 60, Oct. p. 359).

Some Problems of Corrosion and Erosion in a Eucalypt Sulphate Pulp Mill. S. C. Johnson. (Australian Pulp and Paper Industry Technical Association, Proceedings, 1948, vol. 1, pp. 99–105: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 9165). Chipper knives from a 2% C, 12% Cr steel operate about eight times longer than those made of plain carbon steel. Chipper knives of carbon steel developed cracks from fatigue failure which made them useless by the time the cracks were discovered. A magnetic detector enabled cracks to be detected while they were still small enough to be ground out. The digester corrosion of the differential aeration type was caused by the presence of air in solution. Attempts to eliminate the air from the gravity lines and liquors have been generally unsuccessful. The possibility of lining the digesters with mild steel is considered.

Corrosion by Sulphates. W. Z. Friend. (Chemical Engineering, 1948, vol. 55, Nov., pp. 145–147). Data are presented on the rates of corrosion of Monel, nickel, Inconel, Hastelloy, Ni-Resist, ordinary cast iron, and mild steel in liquors occurring in the manufacture of ammonium sulphate, aluminium sulphate, and inorganic acid sulphates.—R. A. R.

Sulphate-Reducing Bacteria and Internal Corrosion of Ferrous Pipes Conveying Water. K. R. Butlin, M. E. Adams, and M. Thomas. (Nature, 1949, vol. 163, Jan. 1, pp. 26–27). Though the essential function of sulphate-reducing bacteria in promoting corrosion of ferrous pipes, etc., in anaerobic soils has long been recognized, their function in internal corrosion has escaped study because of the lapse of time between excavation of the pipe and laboratory study. The authors have been able to examine pipe having heavy internal tuberculated deposits, within two days of their removal from the soil. Considerable quantities of sulphide, sulphur, and elemental sulphur were found in these tubercles, and comparatively large numbers of sulphate-reducing bacteria. It is inferred that the activities of sulphate-reducing bacteria are an important factor in the internal corrosion of ferrous pipes conveying water.—J. P. S.

The Relation between Parent Metal and Coating as a Basis for the Corrosion-Preventing Effect of Protective Coatings. O. Jordan. (Angewandte Chemie, Section B, 1948, vol. 20, Nov., pp. 292–295). The requirements of efficient protective coatings are considered and factors affecting porosity, permeability to water and vapours, adhesion, and passivation are analysed with a view to showing those aspects of corrosion protection requiring further research.—R. A. R.

Testing the Corrosion Protection of Non-Conducting Lacquer Coatings on Food Cans. K. Mehnert. (Archiv für Metallkunde, 1948, vol. 2, No. 4, pp. 140–144). A similar method of measuring the porosity of non-conducting lacquer coatings on the inside of food cans is described. The can is filled with a test solution (*e.g.*, 2% acetic acid, 1–2% citric acid, or 2% NaCl solution) into which a metal or carbon electrode is dipped, and the resistance between the electrode and the can is measured with an alternating-current bridge. The decrease in protection with time of some polyvinylacetate and phenolformaldehyde resins was observed. Precautions to be taken to ensure true results are pointed out.—R. A. R.

The Corrosion Prevention of Paints as a Function of Pigmentation. O. E. Hintze. (Fette und Seifen, 1944, vol. 51, pp. 134–143: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 9200). This report describes a series of 105 experiments on 435 air-drying paints formulated with 74 different pigments and 32 resins. The corrosion of spray-coated steel panels after six weeks' immersion in 3% aqueous NaCl was studied. The general conclusions reached are outlined.

Corrosion of Boiler Steels by Inhibited Hydrochloric Acid. P. H. Cardwell and S. J. Martinez. (Industrial and Engineering Chemistry, 1948, vol. 40, Oct., pp. 1956–1964). Loss-in-weight corrosion tests in hydrochloric acid were made on several types of boiler steel and the effects of different inhibitors were noted. The materials tested included a low-carbon low-silicon steel, a medium-carbon low-silicon steel, a molybdenum steel high in silicon, and a chromium–molybdenum–titanium steel. An arsenic-base inhibitor was the best at all acid concentrations. Ceramic inhibitors gave good results with very dilute acid. Neither the carbon nor the sulphur content of the steel had any apparent effect on the rate of corrosion, but the corrosion in 10% acid increased with the carbon content, especially above 0·2% of carbon. With low carbon contents a low-silicon steel corroded more slowly than a high-silicon steel, but in the medium-carbon range the opposite applied.—R. A. R.

What Can Be Recommended to Overcome the Cracking of Boiler Shells at the Riveted Seams and Other Places, which Develop in Our Present-Day Steam Locomotives. R. McBrian and others. (Official Proceedings of the Master Boiler Makers' Association, 1947, pp. 235–258: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8746). Modern riveted steam locomotive boilers constructed of either alloy or carbon steels have been seriously affected by the cracking at riveted seams. Studies indicate that such failures are due to complex factors involving temper brittleness and ageing of the material, fabrication stress and stress raisers, operating stresses and shocks at the temperature of operation, fatigue failures, intergranular corrosion, and inherent properties of the materials. Tests show that under service conditions there is a loss of elongation and increase in tensile- and yield-strength properties. Impact-energy values indicate that steel at operating temperature becomes more brittle and is susceptible to impact or sudden loads. Stress raisers such as tool marks in rivet holes, sharp edges, and fabrication stresses are found to initiate cracking. Intergranular corrosion can be controlled by use of a proper inhibitor in the water treatment, but the other factors must be controlled by proper design, fabrication, and workmanship.

Temperature and Humidity Factors in the Corrosion of Metals in a Sulphur Dioxide Atmosphere. O. V. Zarubina and M. L. Turich. (Journal of Applied Chemistry, U.S.S.R., 1948, vol. 21, Apr., pp. 362–371 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 16). In the temperature range between 15° and 40° C., at any value of the relative humidity, the main factor in the corrosion of metal surfaces in a sulphur dioxide atmosphere was found to be the temperature. The maximum corrosion was observed from 20° to 25° C. at a relative humidity of 80% or more. Metals or alloys tested were soft iron, cast iron, aluminium, sheet iron, nickel steel, copper, and brass.

Corrosion from Flue Gases. E. A. Rudulph. (Corrosion, 1948, vol. 4, Oct., pp. 476–478). The corrosion of electrostatic precipitators for cleaning flue gases from coal-fired boilers is discussed. Applying concrete coatings with a cement gun was unsuccessful. The trouble was cured by providing the surface of the duct which was exposed to atmospheric temperature with a coating of insulating material. This prevented loss of heat and made it possible to hold the metal of the precipitator chamber at a temperature above the dew point of the stack gases, thus preventing condensation on the metal wall.—R. A. R.

High-Temperature Corrosion of Stainless Steels. W. E. Fontaine. (Metal Progress, 1948, vol. 54, Sept., pp. 332–336). Tests were made by exposing specimens of stainless steel to a constant flow of the products of combustion of butane and air mixed with sulphur dioxide and heated to about 2000° F. The chromium content is the greatest factor controlling the resistance to oxidation of the alloys. Steels with 18% of chromium or less were completely oxidized, whereas with more than 24% of chromium there was only a thin oxide layer. The addition of sulphur dioxide did not increase the corrosion at 2000° F. The corrosion in air at 2000° F. was just as great as in the gases from the butane-air mixture. None of the alloys tested were sufficiently resistant for blades for a turbine driven by gas from a high-sulphur bituminous coal.—R .A .R.

Bone Fixation and the Corrosion Resistance of Stainless Steels to the Fluids of the Human Body. C. G. Fink and J. S. Smatko. (Journal of the Electrochemical Society, 1948, vol. 94, Dec., pp. 271–277). Plates and screws of three stainless steels and a chromium-cobalt alloy, as used for fixing bones, were tested under the most carefully controlled conditions to ascertain their corrosion resistance in conditions closely resembling those prevailing in the normal human body. The 18/8 stainless steel (American Iron and Steel Institute Type 302) had the greatest resistance.—R. A. R.

Principles of Cathodic Protection Design. L. P. Sudrabin and F. P. Macdonald. (Journal of the American Water Works Association, 1948, vol. 40, May, pp. 489–494). Factors affecting the design of cathodic protection equipment for water tanks are discussed and examples are cited to show the differences in dimensions and numbers required for the protection of similar tanks containing water with different contents of dissolved solids.—R. A. R.

Magnesium for Cathodic Protection of a Municipal Piping System. K. D. Wahlquist and O. Osborn. (Journal of the American Water Works Association, 1948, vol. 40, May, pp. 495–503). In 1941 a town called Lake Jackson of 800 houses was built for war workers. About three years later great trouble was experienced from leaks and bursts in buried water pipes. This paper briefly describes the system of cathodic protection which was installed to deal with the situation. A 20-in. cylindrical magnesium anode (Mg about 91%, Al 6%, Zn 3%) was buried between each pair of houses in a hole filled with a quick-setting gypsum mixture. The current density required to protect the steel was approximately 1·0 milliamp./sq. ft., and the galvanic cell produced by the buried anode connected to the buried pipeline was ample to provide the cathodic protection required.—R. A. R.

The Corrosion of Mild Steel by Ammonium Sulphate. A. M. Ward. (Industrial Chemist, 1948, vol. 24, Nov., pp. 722–728). Experiments are described which demonstrate the differences in the corrosion of new and of rusty mild steel plates by ammonium sulphate crystals. In each case a heap (0·5 g.) of the crystals was placed on the plate to cover an area 2 cm. in dia. The heaps were moistened and left at room temperature for 24 hr. The crystals and the products of corrosion were removed and the total iron and ferrous iron were determined. The corrosion of the rusty plate was much greater than that of the new plate and the surface of the former was much more irregular.—R. A. R.

Clad Steel Reduces Corrosion. W. G. Theisinger. (Oil and Gas Journal, 1948, vol. 46, Apr. 1, pp. 275–277 : [Abstract] Centre de Documentation Sidérurgique, Bulletin Analytique, 1948, vol. 5, July, p. 16). The use of corrosion-resistant clad sheet in oil refineries is discussed.

Researches on the Corrosion of Cast Iron by Aluminium and Light Alloys Containing Silicon. (Alpax and Molten High-Silicon Aluminium–Silicon Alloys). P. Bastien and Suzanne Daeschner. (Fonderie, 1948, July, pp. 1217–1235). This is the complete text of an article which appeared in abridged form in *Fonderie*, 1947, Dec., pp. 962–965 (*see* Journ. I. and S.I., 1949, vol. 161, Jan., p. 78).—J. C. R.

Exterior Corrosion of Cast Iron Pipe. K. H. Logan. (Sewage Works, 1948, vol. 20, Jan., pp. 133–137 : Railway Engineering Abstracts, 1948, vol. 3, Dec., p. 321). Soil corrosion is not generally a serious problem for users of cast-iron pipe, because the pipe furnishes its own protection and heavy corrosion of cast iron rarely extends throughout a wide area. Sporadic cases of corrosion caused by unfavourable local conditions occasionally occur and may arise from one of the following: (1) Stray currents from electric railways; (2) differential aeration in two adjacent soils, *e.g.*, a heavy clay and a loose sand; (3) soil alkali; and (4) anaerobic sulphate-reducing bacteria. Where a soil survey or practical experience definitely indicates severe corrosion due to soil, recourse may be made to a protective back-filling (6-in. layer) of clean sand or fine crushed limestone, or to a coating of cement, mortar, or concrete. The graphitic corrosion of cast iron is in some respects self-protecting, as the graphite (ferrous oxide, etc., with less than 20% carbon) tends to plug any pits that are formed. Graphitized pipe will often carry normal gas and water pressures for many years, provided the soil is not unduly corrosive.

Prevention of Scale Formation and Corrosion in Water Supply Systems. (Fuel Economy Review, 1948, vol. 27, pp. 43–47). The prevention of the deposition of calcium carbonate scale from hard water, and of the corrosion of iron pipe by soft water by very small additions of metaphosphate (called "threshold treatment") is described.—R. A. R.

Selected Bibliography on Salt Spray Testing 1935–1946. L. R. Voigt. (Corrosion, 1948, vol. 4, Oct., pp. 492–504). This bibliography contains 160 references with short abstracts from the literature on salt-spray testing.—R. A. R.

Directory of Materials. (Chemical Engineering, 1948, vol. 55, Nov., pp. 116–128). A comprehensive list is presented of corrosion-resistant metals, alloys, cements, ceramics, rubber products, and plastics, in alphabetical order, together with manufacturers' names, composition or description, and most important applications.—R. A. R.

ANALYSIS

Ferrous Metallurgical Analysis Techniques and Their Choice. E. C. Pigott. (Metal Treatment and Drop Forging, 1948, vol. 15, Autumn Issue, pp. 123–131). The basic principles of metallurgical analysis are discussed, and the advantages of various techniques, such as gravimetric, volumetric, colorimetric, polarographic, and spectrographic are considered. Chromatography, spark-testing, and magnetic permeability methods, such as those employed in the Carbometer and Carboanalyser are also studied.—J. P. S.

Precision in Chemical Analysis. A. Lassieur. (Chimie Analytique, 1948, vol. 30, Sept., pp. 197–200; Oct., pp. 220–222; Nov., pp. 254–256). The importance of precision in quantitative analysis is discussed and examples are given for some steels.—R. F. F.

Progressive Norms in Analytical Work. (Zavodskaya Laboratoriya, 1948, vol. 14, Aug., pp. 895–918). [In Russian]. This consists of a number of brief articles in which general questions of the organization of analytical work in industry are discussed, details of analytical techniques in a number of works laboratories in the U.S.S.R. are given with particular reference to time required; various suggestions for improvement are made. A. M. Dymov, pointing out the importance to any industry of an efficient laboratory service, gives an account of some of the improvements in analytical methods which have been introduced in the last ten years and examines the reasons for the apparently limited application of polarographic methods. He urges the exclusive use of colorimetric methods for the determination of most of the elements usually

dealt with in ferrous analysis and the use of semi-micro methods for determinations not amenable to this type of estimation. Energetic measures must be taken to overcome the shortage of laboratory apparatus. M. V. Babaev deals with the difficulty of establishing truly comparative norms and gives some examples of improved methods of ferroalloy analysis adopted by his staff; he describes devices for filtration, in cases where the filtrate is unwanted, and for the rapid cooling of a large number of vessels. P. I. Shportenko states that in his laboratory parallel determinations are generally only carried out for sulphur and carbon, achieving desirable diminution in the consumption of reagents. P. N. Tereshchenko deals mainly with non-ferrous analysis. E. I. Grenberg complains of shortage of apparatus and urges the wider application of methods of internal electrolysis. P. Ya. Yakovlev also complains of shortage of apparatus and of the quality of that available. T. I. Veitsblit mentions the application of spectrographic methods for the determination of a number of elements in carbon and low-alloy steels and the use of such methods is also dealt with by N. E. Klaz. N. V. Tananaev gives details of the determination of phosphorus and molybdenum, and K. A. Nabatova and D. V. Bashkirov, whose laboratory deals with an exceptionally large range of products, mention the adoption of the Bogdanchenko method for the determination of manganese and chromium. K. I. Nikolskaya describes the use of the steeloscope, S. I. Solomonov gives a list of norms for various determinations in his laboratory, and E. Ya. Shmulevich states that the adoption of semi-micro methods of analysis has considerably accelerated determinations. Tables showing the duration of various analyses are given in most of the above articles, and these receive some editorial criticism.—S. K.

Investigation of a Non-Destructive Method for the Analysis of Steels. E. P. Terenteva. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1203–1207). [In Russian]. An account is given of experiments carried out to test the suitability to the rapid analysis of steels under industrial conditions of the method in which the solution for analysis is obtained by the application of a few drops of solvent to the surface of the massive specimen. For satisfactory results to be obtained by this method, it was found that care was necessary in the preliminary preparation of the surface, and for exact duplication of procedure for the standard sample and that under investigation. Full details are given for the determination of manganese and nickel in steel, the accuracy of numerous results being considered. The durations of single determinations of manganese and nickel are stated to be 8–10 min. and 11–13 min., respectively.—S. K.

A New Rapid Method of Quantitative Phase Analysis. L. G. Berg. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1171–1175). [In Russian]. A method of quantitative phase analysis is described whereby each phase in a complex mixture requires 5–12 min. for its determination. The sample is placed in a silica reaction tube, which is then heated in an electric furnace, the evolution of gas being followed by the movement of a drop of mercury in a horizontal graduated tube to which the reaction tube is connected. Water is determined as hydrogen or acetylene after reaction with the hydride or carbide of calcium, respectively. Some refinements of this method are described and several examples of its application to the analysis of mixtures of carbonates and hydrates are given. The enhanced sensitivity of the procedure at low pressure is pointed out.—S. K.

Colorimetric Determination in a Mixture of Two Coloured Components. A. K. Babko and M. M. Korsun. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1160–1170). [In Russian]. Three cases are considered in this study of conditions for the determination of colour intensities in the colorimetric analysis of mixtures of coloured components. First, the formation of two coloured complexes of the different metals or the presence of a coloured foreign ion is dealt with. It is shown that with a proper choice of the spectral range no special optical devices are necessary, the determination of chromium and manganese being described to illustrate this. Secondly, the various means available for dealing with the use of a reagent which is itself coloured are considered. Finally, the coloured co-ordination compounds of iron with salicylic acid are discussed as an example of colorimetric determination in the case of the formation of more than one coloured complex with a given ion.—S. K.

The Determination of Chromium in Iron and Steel. (Metallurgia, 1948, vol. 39, Nov., pp. 41–45). This is a report by the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association. A method of analysis utilizing the principle of silver-nitrate/ammonium-persulphate catalytic oxidation, previously tested for low-chromium steels, has been examined with a view to extending its application to a wide variety of chromium steels. A procedure is described by which the method is applicable to all classes of chromium steel, including high-manganese steel, tool steels of the high carbon and of tungsten high-speed types, and the complete range of stainless and austenitic corrosion and heat-resisting steels.—R. A. R.

New Designs of Capillary Microburettes. I. M. Korenman and A. P. Rostokin. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1391–1392). [In Russian]. Some designs of capillary microburettes are given together with their sensitivities. Details of procedure for using this type of instrument with solutions of permanganate, dichromate, etc., are mentioned.—S. K.

Apparatus for Determining Carbon. M. V. Babaev. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1392–1394). [In Russian]. A number of faults in the present construction of gas-metering apparatus for determining carbon in ferroalloys are considered, and an improved design is suggested for dealing with carbon contents of up to 8% in various materials.—S. K.

Analyzing Malleable Iron. A Rapid Method for Cr, Si, and Mn Determinations. W. B. Sobers. (American Foundryman, 1948, vol. 14, Sept., pp. 56–58). A closer control of residual alloys is necessary for malleable iron than for cast irons, and wrought or cast steels, otherwise graphitization may be retarded and the resulting iron is low in ductility and has poor machinability. In this article details are given of a practical and rapid method for determining the contents of chromium, silicon and manganese by chemical analysis.

J. C. R.

X-Ray Fluorescence Analysis. J. L. Abbott. (Iron Age, 1948, vol. 162, Oct. 28, pp. 58–62; Nov. 4, pp. 121–124). In fluorescent X-ray analysis a high-intensity X-ray beam is projected upon the specimen, when secondary radiations typical of the constituents of the specimen are emitted; these are collimated and thrown on to a rock-salt crystal which diffracts them according to their wavelengths. These wavelengths and the intensity of each radiation are measured with a Geiger counter. Quantitative analysis is therefore possible. The absorption effect of other elements on the lines under study must be allowed for; this is greatest for elements of high atomic number.—J. P. S.

Carbon and Sulphur. Combustion Technique in the Laboratory. J. Winning. (Iron and Steel, 1948, vol. 21, Dec., pp. 615–617). A description is given of a laboratory method for the determination of carbon and sulphur by combustion in oxygen. This method is suitable for dealing with most ferrous materials including free-cutting steels with 0·3% sulphur. Possible sources of error and means of minimizing them are discussed.—J. C. R.

Improved Double Tubular Furnace of the Mars Type. B. K. Podkorytov. (Zavodskaya Laboratoriya, 1947, vol. 13, pp. 634–635; Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8541). A silicon carbide furnace with two tubes, for the determination of carbon and sulphur in ferrous metals is described.

Determination of Calcium and Magnesium in Iron Ore Using a Cation Exchange Base. Iu. I. Usatenko and O. V. Datsenko. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1323–1327). [In Russian]. The adsorption of the ions of calcium and magnesium by ferrous hydroxide was investigated and found to be so extensive as to make the ammonia-precipitation of iron undesirable in ore analysis. A method for the separation of calcium and magnesium from iron was therefore developed, which is based on the use of Wolfatite, and data are presented showing the effect of the acidity of the solution on the adsorption of the above alkaline earth metal ions by this substance. Results obtained by the use of this method for the analysis of two iron ores and a sample of blast-furnace flue dust agreed well with those arrived at by the usual methods. Some variations of the cationite method are given.—S. K.

Colorimetric and Photometric Absorption Analysis. D. J. Coumou. (Analytica Chimica Acta, 1948, vol. 2, Dec., pp.

693–703). A survey is given of colorimetric and photometric absorption analysis. The principles of measuring methods and the main points in the construction of various instruments are discussed.—R. A. R.

Modern Trends of Polarographic Analysis. J. Heyrovsky. (Analytica Chimica Acta, 1948, vol. 2, Dec., pp. 533–541). Examples of improved methods of polarographic analysis are cited. One of these is a procedure for determining chromium in steel. A sample of 1–2 g. is carefully weighed and dissolved in conc. HCl, and two exactly equal volumes, *e.g.*, 10 c.c. are placed in each of two 100 c.c. flasks ; a known amount of carefully prepared standard K_2CrO_4 is added to one flask. To each is added 3 c.c. of 30% H_2O_2, and, while stirring, 40 c.c. of 2*N* NaOH are put in dropwise ; chromate is thus formed and H_2O_2 decomposed on boiling. After cooling, 3 c.c. of 0·5% gelatine are added and each flask is filled to the 100 c.c. mark. Polarograph curves are recorded after the removal of oxygen. The chromate solution containing the standard addition shows a higher wave than that due to the sample alone. The amount of chromium in the sample is then obtained by

$$x = \frac{a \times h_x \times 100}{(h - h_x)w}\%$$

where a is the weight of chromium in the standard addition and w the weight of the sample.—R. A. R.

Visual Polarograph Made by U.B.A.S. A. G. Stromberg and I. E. Bykov. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1380–1382). [In Russian]. This is a description of the latest model of visual polarograph constructed by the Ural Branch of the Academy of Sciences. Some details of its capabilities are given.—S. K.

The Forced Shaking-Off of the Drop in Polarographic Investigations. P. N. Tereshchenko. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1319–1322). [In Russian]. A mechanism is described for rhythmically tapping the capillary tube of the mercury electrode so that the drops of mercury may be shaken off at a controlled rate, some applications of this technique being given.—S. K.

On the Application of Solid Electrodes for Polarographic Analysis. S. K. Chirkov. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1300–1306). [In Russian]. Polarographic analysis using platinum electrodes is described, the procedure and interpretation of results being compared with mercury-electrode practice.—S. K.

A Quick and Accurate Method of Determining Small Contents of Carbon in Steel. B. K. Podkorytov. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., p. 1262). [In Russian]. A brief account is given of a modification of the Wirtz apparatus for the determination of small quantities of carbon in steel, the accuracy of the results obtained by this method being superior to that obtained by the baryta method. The duration of each determination is 6–8 min.—S. K.

On the Application of Solid Electrodes in Polarography. E. M. Skobets, I. D. Panchenko, and V. D. Ryabokon. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1307–1312). [In Russian]. The construction of a polarographic cell in which the solid cathode is periodically dipped in the mercury anode by a suitable mechanism in described and some results obtained by the use of this apparatus are presented and discussed.—S. K.

The Electrical System of the Visual Polarograph. A. G. Stromberg. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1382–1387). [In Russian]. Two conditions are given which should be satisfied by any arrangement of the rheostat in the circuit of the visual polarograph : (1) The total resistance of the shunts is equal to the critical resistance of the mirror-galvanometer within ± 5% for any setting ; and (2) the ratio of sensitivities for two given settings of the sensitivity-regulator does not vary for different settings of the rheostat. A number of different circuits are critically examined on the basis of the above criteria, equations being derived to show the influence of resistances on the working of the polarograph. Various parameters of the circuits and individual resistances for optimum results are calculated.—S. K.

The Analysis of Industrial Problems—Coordinated Spectroscopy and X-Ray Diffraction. W. J. Poehlman and W. A. Kluck. (Non-Destructive Testing, 1948, vol. 7, Summer Issue, pp. 19–22). Examples are given of how spectroscopic and X-ray diffraction analyses can be co-ordinated to determine the major, minor and residual constituents of a substance, to identify the important compounds or metallurgical phases present, and to obtain information on particle size, presence of strain, extent of solid solution, and degree of preferred orientation.—R. A. R.

A Field X-Ray Spectrum Apparatus. M. A. Blokhin. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1351–1355). [In Russian]. A self-contained unit for qualitative and semi-quantitative X-ray analysis in the field is described. The power requirements are supplied by a petrol-driven generator, the consumption of fuel per analysis being about 1 litre. S. K.

Use of Solid Electrodes in Spectral Analysis. A. Pokorný. (Chemické Obzor, 1948, vol. 23, pp. 101–105 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8537). The various terminal forms of electrodes and the most suitable form for the quantitative analysis of steel and cast iron are discussed.

Spectrographic Determination of Arsenic in Steel. E. I. Nikitina. (Zavodskaya Laboratoriya, 1947, vol. 13, p. 885 : Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8699). The method was developed to determine arsenic in steel made from iron ores containing arsenic. A large autocollimation spectrograph of the Hilger type was used. The source of excitation was an A.C. arc. The most satisfactory line for analysis, based on intensity and distribution, is the line As I 2349·84A. which is sufficiently sensitive to arsenic concentrations encountered (0·085%, 0·13%, and 0·36%). The neighbouring line Fe I 2350·39A. was used for comparison. The lines were photometered by the method of photometric interpolation. A pointed carbon rod was used as the second electrode ; the use of copper and iron rods as constant electrodes gave less satisfactory results. The width of slit in the spectrograph was 0·02 mm., distance between electrodes was 2 mm., current strength was 10 amp., and exposure time was one minute. A medium-type model spectrograph can be used for these analyses.

Corrigenda

The following corrections to abstracts in the January *Journal* should be noted : Page 62, first abstract, first word should be " Precision "; page 62, col. 2, abstract 8, the author's name should be A. S. Lundy ; page 68, col. 1, abstract 9, the reference should be " Electrodepositors' Technical Society, Advance Copy "; page 76, col. 2, abstract 6, the author's name should be A. G. Peacock ; page 79, col. 1, abstract 5, the first author's name should be S. P. Ewing.

In the February issue page 154, col. 2, abstract 8, the author's initials should be A. F. ; page 155, col. 1, abstract 9, the author's initials should be R. T. ; page 161, col. 1, abstract 6, the year should be 1948.

Quantitative X-Ray Spectral Analysis by the Method of the Width of Standard Line. I. B. Borovskii. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1335–1343). [In Russian]. A review of methods of quantitative spectrum analysis is followed by an account of a technique for use with X-rays, both theoretical and practical aspects of the latter being discussed.—S. K.

Moly Mold Samples Increase Accuracy of Spectrographic Analysis. H. A. Tuttle and F. R. Bryan. (Iron Age, 1948, vol. 162, Dec. 23, pp. 57–59). In the preparation of pencil-rod samples for spectrographic analysis it has been found valuable to use pure molybdenum moulds. The phosphorus taken up and the porosity are less than with iron moulds. J. P. S.

Spectroscope Used to Identify Stainless Grades. (Steel Processing, 1948, vol. 34, Nov., pp. 598–599). A brief description is given of the spectroscope used by the Carnegie-Illinois Steel Corp. to distinguish one grade of stainless steel from another. The working range and limitations of the instrument in detecting chromium, nickel, columbium, titanium, molybdenum, aluminium, tungsten, and copper are given.—R. A. R.

The Complete Spectrochemical Analysis of High Percentage Alloys. (Applied Research Laboratories, 1948, Pamphlet). There is a need for generalizations which will permit spectrochemical methods of analysis to be used for the determination of elements irrespective of the percentage range involved ; this applies particularly to alloys containing more than 10% of certain elements. One of the difficulties is the method of

calculation suitable for complex systems. In this pamphlet J. H. Coulliette's method of calculation is critically examined, the conditions limiting its application are pointed out, and a new method of calculation is explained with an example of its application to silver alloys.—R. A. R.

Analysis of Low Alloy Steels with the Quantometer. (Applied Research Laboratories: Spectrographer's News Letter, 1948, vol. 11, Jan., No. 6). A brief description is given of the advantages obtained by using the Quantometer for making simultaneous determinations of several elements. Results obtained with low alloy steels and data on the degree of accuracy are given. (The Quantometer is the direct-reading instrument described by M. F. Hasler, J. W. Kemp, and H. W. Dietert, *see* Journ. I. and S.I., 1946, No. II, p. 143A).—R. A. R.

The Spectrochemical Analysis of Low-Alloy Steels with the Quantometer. M. F. Hasler. (Applied Research Laboratories, 1948, Apr., Pamphlet). The direct-reading spectrographic apparatus (*see* preceding abstract) and the procedure for operating it are described in detail, including some refinements developed since the initial description by M. F. Hasler, J. W. Kemp, and H. W. Dietert. Samples can be analysed at the rate of one every 2 min. the time including grinding the sample, sparking and reading certain elements and then arcing and reading the remainder of the elements of interest. Readings of up to twelve elements can be taken as well as recorded.
R. A. R.

Sorting Pig Iron on the Basis of Thermoelectric Determination of Silica Content. A. V. Golovin. (Zavodskaya Laboratoriya, 1947, vol. 13, pp. 886–887: Chemical Abstracts, 1948, vol. 42, Nov. 20, col. 8744). The thermoelectric apparatus used successfully to sort steel in aviation plants was used to sort pig iron on the basis of silicon content. For a silicon content of 0·17–0·37% the pointer of the galvanometer deviates to the left from zero and for large silicon contents it deviates to the right. By using steels 38KhA (0·17–0·37% Si) and 30 KhGSA (0·90–1·20% Si) the galvanometer was standardized for use in determinations.

Analytical Methods in Plating Baths. J. B. Mohler and H. J. Sedusky. (Metal Finishing, 1948, vol. 46, Nov., pp. 68–75). Brief descriptions are given of procedures for the determination of acids and metals in plating baths.—R. A. R.

The Analysis and Testing of Solid Fuel. A. H. Edwards. (Monthly Bulletin of the British Coal Utilisation Research Association, 1948, vol. 12, Aug., pp. 281–290; Sept., pp. 317–322; Oct., pp. 353–363). The work of previous investigators is reviewed. The first part covers approximate and ultimate analysis, the second calorific value and mineral matter, and the third part, calorization, petrology, reactivity. The bibliography contains 166 references.—R. F. F.

The Quantitative Determination of Dust in Gas. A. H. Arbogast. (Iron and Steel Engineer, 1948, vol. 25, Oct., pp. 82–89). Various methods of determining dust in gases are described. These include wet scrubbing and filtration methods, the sugar-filtration method, the cotton-bag filtration method and the paper thimble method for the separation and collection of dust. An account is also given of an improved method in which a woven glass-cloth bag is used. Brief notes are given on the measurement of gases by orifice plates, laboratory wet test meters, and dry or diaphragm test meters, and on moisture determination.—J. C. R.

Mercury-Sealed Bulbs for Gas-Analysis Apparatus. M. I. Rozengart. (Zavodskaya Laboratoriya, 1948, vol. 14, Nov., pp. 1394–1396). [In Russian]. Pressure-volume curves are given for various types of mercury-sealed bulbs used in gas analysis, and some difficulties of manipulation are considered.
S. K.

New Methods of Gas Analysis. W. J. Gooderham. (Journal of the Society of Glass Technology, 1948, vol. 32, Aug., pp. 216–223). **Recent Development in a New Method of Gas Analysis.** W. J. Gooderham. (Analytica Chimica Acta, 1948, vol. 2, Dec., pp. 452–464). The author describes apparatus and methods of analysing industrial gases in which the gas mixture passes through a meter, a reagent to remove one constituent, another meter, another reagent, and so on. The meters consist of graduated tubes up which a soap film travels with the flow of gas; the movement can be stopped by opening a by-pass tap. The difference in length traversed by the soap films in meters before and after the absorbent indicates the amount of gas absorbed.—R. A. R.

A Modified Orsat Apparatus for Analysis of Purified Coke-Oven Gas. H. W. Deinum and J. W. Dam. (Analytica Chimica Acta, 1948, vol. 2, Dec., pp. 501–509). Ethane in coke-oven gas cannot be determined with the usual Orsat apparatus, the value obtained for methane being the sum of methane and ethane. A modified apparatus and the procedure are described which enable ethane to be determined without any appreciable increase in the time taken.—R. A. R.

Analysis of Blast-Furnace and Coke-Oven Gas. B. Dupuis. (Société Française de Métallurgie: Iron and Coal Trades Review, 1949, vol. 158, Jan. 7, pp. 23–24). The method of analysing blast-furnace and coke-oven gases at a French works is outlined. Results obtained showed abnormal methane contents and were found to be inaccurate. Possible sources of error are discussed and means of overcoming them are outlined.—J. C. R.

HISTORICAL

"Smelting Iron Ore with Coke and Casting Naval Cannon in the Year 1775." (Edgar Allen News, 1948, vol. 27, Dec., pp. 194–195; 1949, Jan., pp. 213–215). This is a translation, with an introduction and notes, by W. H. Chaloner of the report by Marchant de la Houlière on his visit to several English ironworks in 1775 to study the smelting of iron ore with coke, the making of wrought and cast iron, and the casting of guns.

Early Ironworking near Ticehurst, in Sussex. H. R. Schubert. (Journal of The Iron and Steel Institute, 1949, vol. 161, Jan., p. 16). Documents in the "Dunn Collection" at Hove contain twenty-one records regarding ironworking in south-east Sussex from 1433 to 1715. The author quotes evidence from these relating to sites of ironworks, near Ticehurst, Sussex, and shows how it supplements the accounts in Straker's "Wealden Iron."—R. A. R.

The Superiority of English Cast-Iron Cannon at the Close of the Sixteenth Century. H. R. Schubert. (Journal of The Iron and Steel Institute, 1949, vol. 161, Feb., pp. 85–86). Evidence from old documents is cited to show that iron cannon cast in England during the reigns of Elizabeth and James I were considered to be of very good quality, and were in great demand from the Continent.—R. A. R.

Colonial Foundries in the New World. B. L. Simpson. (American Foundryman, 1948, vol. 14, Sept., pp. 24–31). The growth of the iron foundry industry in the 17th and 18th century in North America is traced. Reference is made to some of the early operators and their works, in particular to the Saugus Iron Works.

ECONOMICS AND STATISTICS

World Production of Iron. R. Durrer. (Instituto del Hierro y del Acero: Von Roll Werkzeitung, 1949, vol. 20, No. 1, pp. 3–9). The past and present production of iron and steel in the different countries of the world is reviewed, and the trends of future production are discussed.—R. A. R.

Analysis of Trends in Europe's Supply and Consumption of Iron and Steel Scrap. (Jernkontorets Annaler, 1948, vol. 132, No. 12, pp. 485–500). [In Swedish]. This is a Swedish translation of a report (E/ECE/84) presented by the Secretariat of the Economic Commission for Europe.—J. K.

German Bizone Steel Capacity—Steel Ingots and Castings. (Iron Age, 1948, vol. 162, Nov. 11, p. 148). A list of German steelworks in the English and American occupied zones, showing their productive capacities when dismantling has been completed, is presented. It is divided into three classes: Already dismantled, dismantling in progress or intended, and, scheduled to remain. A curve shows that the capacity in October, 1948 was almost 7 million tons, and that by January 1951 it is expected to rise to 12·8 million tons.
R. A. R.

The Iron and Steel Bill. (British Iron and Steel Federation, Statistical Bulletin, 1948, vol. 23, Nov., pp. 1–26). The purpose of this article is to contribute towards an understanding of the main implications of the Iron and Steel Bill so far as organization is concerned, and to elucidate some of the points of difference which will arise when this is compared with the present organization of the industry. A full summary of the Bill is given in an appendix.—R. A. R.

The Iron and Steel Bill in Practice. H. E. Crawfurd. (New English Review Magazine, 1949, vol. 2, Jan., pp. 36–41). The author discusses whether the organization described in the clauses of the Iron and Steel Bill will in practice give the steel required at home and for export.—R. A. R.

MISCELLANEOUS

Sludge Clearance. Electrically Operated Dredger for Turkish Steelworks. (Iron and Steel, 1948, vol. 21, Dec., p. 605). A brief illustrated description is given of an electrically operated suction cutter dredger used for clearing silt from the sedimentation pond at the Karabük Iron and Steel Works in Turkey.—J. C. R.

The Use of Electric Welding Equipment to Thaw Out Frozen Mains. R. Marek. (Schweisstechnik, 1948, vol. 2, Nov., pp. 139–141). Recommendations are made on the use of welding generators to supply a heavy current to frozen pipelines in order to melt the ice and free them. Depending on the size of the pipeline from 80 to 800 amp. are required, but 300 amp. are sufficient for most uncovered lines in workshops. Data on the size of connecting cables, current strengths, and thawing time for different sizes of pipe are given.—R. A. R.

Water in Iron and Steel Mills. R. Colas. (Eau, 1948, vol. 35, pp. 75–95 : Chemical Abstracts, 1948, vol. 42, Oct. 20, col. 7687). This is a report on the water problem in the French iron and steel industries. A bibliography of twenty-six references is appended.

Removal of Silica in a Sludge-Blanket Hot-Process Softener. J. D. Voder, H. Y. Carbonnier and A. H. Morris. (Power, 1948, vol. 92, July, pp. 75–77, 156, 158 : [Abstract] Monthly Bulletin of the British Coal Utilization Research Association, 1948, vol. 12, Sept., pp. 334–335). A lime-soda softener was replaced by a sludge-blanket softener and a phosphate softener. The silica content in the feed water was greatly reduced, the hardness and turbidity were lowered and the consistency was less affected by interruption of the chemical feed.

The Removal of Copper, Brass and Bronze Coatings from Scrap and Waste Materials. E. T. Richards. (Archiv für Metallkunde, 1948, vol. 2, No. 4, p. 137). Chemical and electrolytic methods of removing copper, brass, and bronze coatings from ferrous and non-ferrous metal scrap are briefly reviewed.—R. A. R.

BOOK NOTICES

CHESTERS, J. H. "*Iron and Steel.*" 8vo, pp. ix + 116. Illustrated. London, 1948 : Thomas Nelson and Sons, Ltd. (Price 5*s.*).

In this book Dr. Chesters tells the story of the manufacture and use of iron and steel. Throughout the book, Dr. Chesters has avoided the use of scientific language understood only by the few and has thus produced a book which, while offending none, anyone can read and enjoy.

The book is so nicely and clearly printed and Dr. Chesters' style is so good that, after reading the first paragraph of the first chapter one feels that one must finish the chapter, and, having finished the first chapter, one feels that one must read the whole book. From some points of view it is an elementary book, but it is quite free from technical errors, unlike so many so-called elementary books or introductions to metallurgy.

Chapter 1 is of the nature of an hors-d'oeuvre and, as already stated, encourages one to read on. The second chapter deals with the science behind metallurgy, particularly the metallurgy of iron and steel. In a few simple words the author covers the fundamental theory of steel-making and gives a very clear picture of what happens throughout the various processes.

Chapter 3 is devoted to a consideration of raw materials. A description of the manufacturing processes starts in chapter 4 which is devoted to blast-furnaces. In the next chapter open-hearth furnaces are described, and here reference must be made to an imaginary section through an open-hearth furnace which appears on page 45; this is remarkably clear and understandable.

Chapter 6 is devoted to a consideration of the Bessemer process, whilst electric furnaces are adequately covered in chapter No. 7. Then follows a chapter describing the shaping and treating of iron and steel. The testing of the product is covered by chapter 9.

The last chapter is a short historical survey and is well described by its title "Past, Present and Future." The book concludes with a glossary of metallurgical terms.

J. FERDINAND KAYSER

MANLEY, R. G. "*Fundamentals of Vibration Study.*" Second edition revised, 8vo, pp. xvi + 156. Illustrated, London, 1948 : Chapman and Hall, Ltd. (Price 15*s.*).

The aim of this little book is to carry the student from the stage in which he "has gone but a little way beyond the matriculation syllabus" to that at which he can profitably read a standard textbook on the study of vibrations. The author's approach is clear and direct. He spends no time discussing questions of convergence and validity which are of no interest to the practical engineer. Instead, he concentrates on detailed treatments of those parts of the subject which a beginner is liable to find the most confusing. He is most lucid in dealing with the vexed question of units and dimensions, and, since he has to satisfy the physicist who measures mass in pounds, the engineer who uses inch-slugs of 386 lb., and the aerodynamical engineer who uses foot slugs of 32·2 lb., this is no mean feat. The more advanced methods, such as Rayleigh's method for approximating to the lowest resonant frequency the determinantal form of the secular equation, and the systematic step-by-step treatment of oscillatory elements in series, are introduced in a natural way. One of the few criticisms which can be made is that Rayleigh's method is said merely to give an approximation, whilst it follows at once from the theorem quoted on page 65 that the frequencies of constrained modes separate those of the unconstrained modes that this estimate is always too high. The treatment of the separation of variables in a partial differential equation omits an elementary, but essential step, and the use of the term "phase velocity" for 2π times the frequency is unfortunate in view of the well-established use of this phrase in a different sense in the study of wave motions. But these are minor blemishes in an excellent text.

In this new edition the author has added introductory and summarizing sections to each chapter. There are some fresh examples, and some misprints in the old edition have been corrected. There are two new appendices, one outlining the practical application of the principles developed in the text, and the other containing tables of functions of especial importance in vibration studies.

F. R. N. NABARRO

PHILOSOPHICAL MAGAZINE. "*Natural Philosophy through the 18th Century and Allied Topics.*" Edited by Allan Ferguson. 8vo, pp. viii + 164. London, 1948 : Taylor and Francis, Ltd. (Price 15*s.*).

Commemoration numbers of magazines are often a great disappointment and little more than thinly veiled advertisements. That does not, however, apply to the commemoration number to mark the 150th Anniversary of the foundation of the *Philosophical Magazine*.

This 164-page publication is most interesting, and from reading it it is obvious that great as may be the advances made during the 20th century, many great and important advances were made during the 18th century.

The articles cover astronomy, physics, chemistry, mathematics, engineering and inventions, scientific instruments, scientific societies, teaching of the physical sciences, and there is an article on the scientific periodical from 1665 to 1798.

Each article has been written by a specialist who must have devoted much time and study to his subject.

The article that most attracted the reviewer was F. Sherwood Taylor's "The Teaching of the Physical Sciences at the end of the 18th Century." Taylor gives a number of tables showing the type of education received by a number of men who made a lasting name for themselves. It is interesting to note that Ampère (born 1775) educated himself privately in mathematics, that Dalton (born 1766) was self-educated, that G. Stevenson (born 1787) had no education, and that C. Wheatstone (born 1802) started life as a musical instrument maker.

Out of a total of 68 scientists, Taylor points out that 15 were without higher education, six had a higher mathematical education, 28 started life with a pharmaceutical or medical education, and four had a scientific higher education other than medical, and he concludes that the evidence

shows that the main avenue that led to scientific eminence was the private pursuit of scientific studies by those who had no formal training.—J. FERDINAND KAYSER

SMITH, D. "*Metalwork.*" An Introductory Historical Survey. 8vo, pp. 64. Illustrated. London, 1948: B. T. Batsford, Ltd. (Price 7*s.* 6*d.*).

From the point of view of the pure metallurgist this is rather an unusual book, but it is very interesting. The author tells the story of the development and use of metal by man from the earliest times until the introduction of the machine. It is a book that it is worth while to read and to remember, and a knowledge of its contents will add to the interest of visits to museums and of motor excurisons around the country when those who have read this interesting little book will view with still greater interest the many fine wrought iron gates that are to be found about the English countryside.

The illustrations are well worth looking at for their own sake, and undoubtedly the most fascinating one is the coloured reproduction of a prehistoric bronze shield with enamelled bosses, which serves as frontispiece.

J. FERDINAND KAYSER

INSTITUTE OF PHYSICS. "*The Measurement of Stress and Strain in Solids.*" ("Physics in Industry"). 8vo, pp. xi + 114. London, 1948; Institute of Physics. (Price 17*s.* 6*d.*).

The Manchester and District Branch of the Institute of Physics held a three-day conference in July 1946 on the study and measurement of stress and strain, and the report of this conference forms the present volume, edited by Dr. F. A. Vick. Almost all the contributors are, or were at the time of the conference, in the government service.

The first, and longest, paper is an account by the late Eric Jones of practical experience with wire-resistance strain gauges. This should be of value both to those who wish to use these new and versatile instruments, and to those who wish to understand the physical principles underlying the techniques which have been developed. There follow papers on electrical circuits suitable for combining the readings of several gauges in order to eliminate unwanted effects, on the increased sensitivity of strain gauges when used in high-frequency ($\frac{1}{2}$ – 20 megacycle circuits instead of in the conventional direct-current circuits, and on the use of resistance strain gauges in ships.

The recent development of photoelasticity is reviewed by W. A. P. Fisher. Since the early work of Coker and Filon in this country the main centre of activity seems to have shifted to the U.S.A. In the next paper, H. McG. Ross of the Kodak Research laboratories discusses the photography of photoelastic stress patterns. His remarks are illustrated by the magnificent picture of the isochromatic lines of the dynamic stresses at the instant of impact of a hammer and nail which forms the frontispiece of the book. A further note discusses the elimination of time-edge stresses in bakelite plastics.

D. E. Thomas gives a clear account of the methods used to measure strains in metals by means of X-rays, and of the principles underlying them. Unfortunately the article seems to have been prepared at a time when it was not clearly realized that the X-rays are reflected from a group of lattice planes in a special orientation and that, owing to the elastic anisotropy of the metal, the stress in the small group of grains which contain planes in that orientation may differ appreciably from the mean stress. The paper is followed by a brief note on the technique of X-ray stress measurement on board ship.

There are papers on mechanical extensometers, on a novel acoustic strain gauge, and a final article by G. E. Bennett, which deals with variable inductance and variable capacitance strain gauges, and discusses in detail their associated electrical circuits.

F. R. N. NABARRO

NEW PUBLICATIONS

BAINBRIDGE, C. G. "*Gas Welding and Cutting.*" Pp. 305. London: Louis Cassier Co., Ltd. (Price 15*s.*).

BASHFORTH, G. R. "*The Manufacture of Iron and Steel.*" Volume I.—"*Iron Production.*" 8vo, pp. viii + 228. Illustrated. London, 1948: Chapman and Hall, Ltd. Price 21*s.*).

BERTORELLE, E. "*Galvanotecnica.*" 8vo, pp. xvii + 464. Illustrated. Milan, 1947: Ulrico Heopli.

BRITISH STANDARDS INSTITUTION. B.S. 1448: 1948. "*Nomenclature of Decorative Metallic Finishes.*" 8vo, pp. 6. London: The Institution. (Price 2*s.*).

BRITISH STANDARDS INSTITUTION. B.S. 1461–63: 1948. "*Chromium–Molybdenum Steel Castings*" 8vo, pp. 13. London: The Institution. (Price 2*s.*).

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